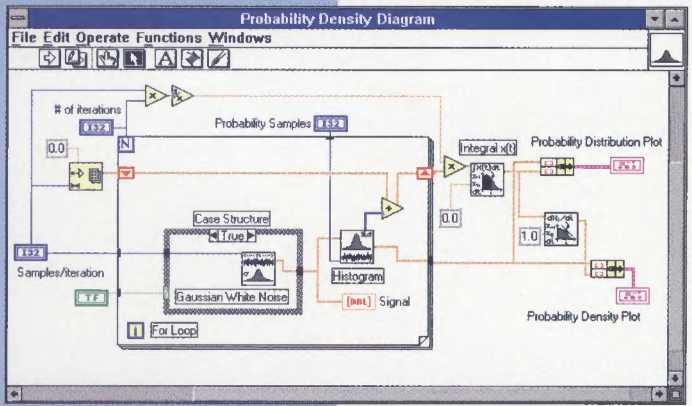
DATA COMPRESSION

IEEE SPECTRUM

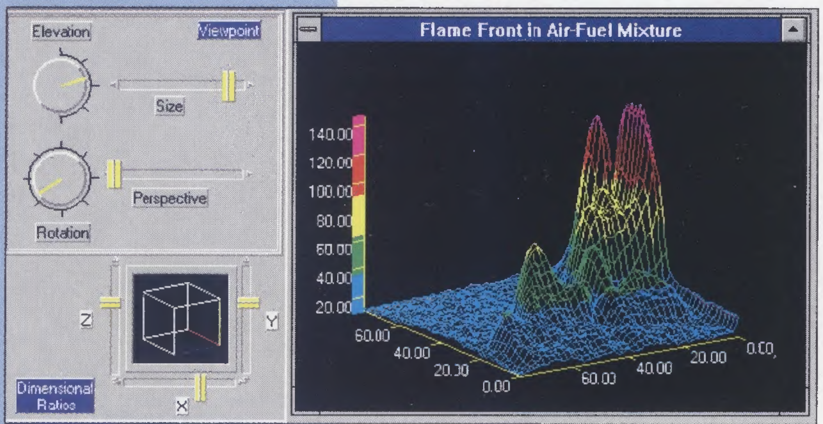
JOBS AT RISK

AUGUST 1993 THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

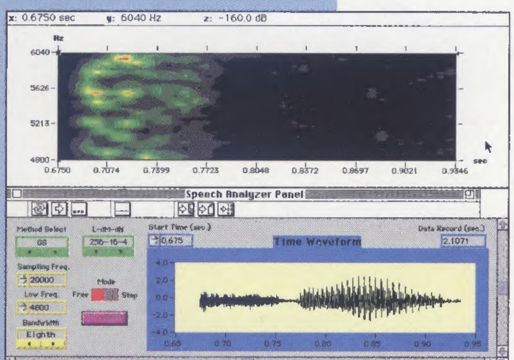
Draw Your Complete Analysis Solution with LabVIEW® Graphical Programming



LabVIEW is a complete graphical programming language.



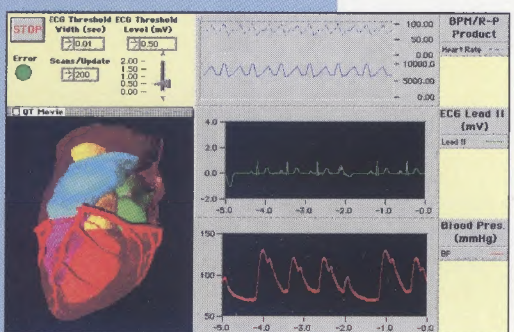
Surface plot of a flame front using LabVIEW and the SurfaceView toolkit.



Data courtesy of NIH.

Gabor Spectrogram
National Instruments

The Gabor Spectrogram displays a portion of the sentence "I take two people out for breakfast," computed and displayed with LabVIEW.



EKG signal and QuickTime heart video using LabVIEW.

Productive and Creative Methodology

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Advanced Visualization and Plotting

Rapidly create spectrograms, 2D plots, 3D plots, waterfall plots, strip charts, contours, and XY graphs with annotation, printing, and importing.

Powerful Mathematics

The award-winning LabVIEW Gabor Spectrogram algorithm for joint time-frequency analysis (JTFA) is an example of industry-leading innovation. In addition, LabVIEW has hundreds of analysis function blocks for signal processing, digital filters, statistics, and linear algebra. Add-on analysis toolkits include:

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- surface rendering
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- 3D plotting
- speech processing
- JTFA

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Acquire data from GPIB, VXI, and RS-232 instruments and plug-in data acquisition boards. Connect to other applications with DDE, Apple Events, QuickTime, or TCP/IP. With the open design of LabVIEW, you can easily call C programs and other languages. In addition, LabVIEW executes at speeds comparable to compiled C code.

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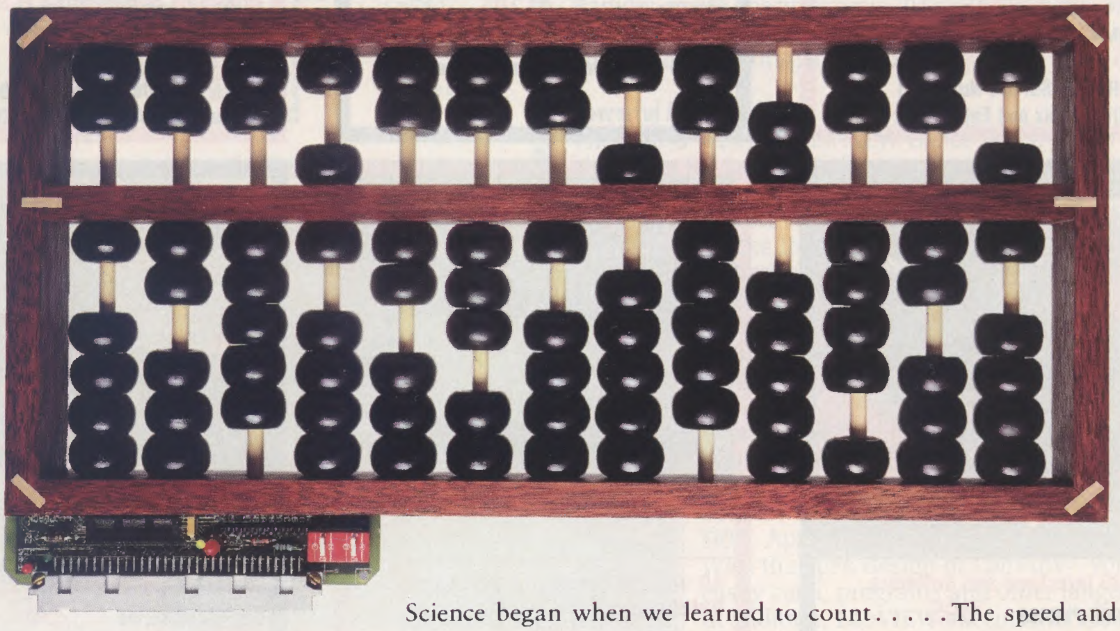
Circle No. 12

INVESTING IN THE GENIUS OF THE MIND



Science began when we learned to count. . . . . The speed and precision with which we calculate still paces our progress. . . . . in theory and application. . . . . physically. . . . . intellectually. . . . . practically. . . . . For 50 years the David Sarnoff Research Center has counted on the genius of the mind. . . . . One result is the convergence of video and computing that in 1989 produced the "Princeton Engine". . . . . This video supercomputer was originally designed to speed up development and testing of signal-processing circuits and systems for High Definition TV. . . . . The Princeton Engine now simulates highly complex environments, to help speed developments in medicine, engineering, architecture, aerospace–any discipline where innovation is at a premium. . . . . Today at the Sarnoff Research Center, we continue David Sarnoff's drive to "Amaze the world," by counting on the best of technology to serve our corporate and government clients, worldwide. . . . . For information call: Public Affairs, David Sarnoff Research Center, CN 5300, Princeton, New Jersey 08543-5300 (609)734-2507. When you wish to count on the genius of the mind. . . . .

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Circle No. 33

Newslog

JUNE 10. U.S. trade representative **Mickey Kantor** said Germany had broken ranks with the **European Community** (EC) to strike a surprise telecommunications deal with the United States that enables U.S. companies to bid openly with European companies for **German government** contracts. The EC earlier this year had adopted a rule favoring European companies over outsiders in bidding for EC utilities' business. EC officials commented it was the first time a member struck an outside deal that appears to violate the community's rules.

JUNE 10. An international group of 116 scientists and radiation experts released a report at the **Woods Hole Oceanographic Institution** in Massachusetts saying that nuclear wastes dumped into the oceans for decades apparently posed no global danger. But the group said locally high concentrations could be a danger if picked up by marine life and hence into the food chain.

JUNE 14. Hitachi Ltd., Tokyo, said it had developed a high-density bi-CMOS IC that can operate at high speeds even at low voltage. The unit is 60 percent faster than CMOS units, even when it is operated at 2.5 V, half what runs conventional bi-CMOS models. The company maintains the speed by using a diode to make up for the lower voltage.

JUNE 16. California's Air Resources Board said it had approved Detroit-based **Chrysler Corp.**'s electrically powered Dodge Caravan as a zero-emission vehicle four years ahead of a state deadline. The certification is the first for a leading auto maker under rules requiring 2 percent of the vehicles sold in the state to be pollution free by 1998. The company said it would complete 50 vans this fall, for US $120 000 apiece. Each uses thirty 6-V batteries with a life expectancy of 150 000 km and an operating range of 130 km between charges.

JUNE 16. The **European Commission,** meeting in Luxembourg, Belgium, said that at least six European Community countries, including the largest member states, had agreed to open all domestic and international telephone calls to non-European competition by 1998. But poorer and smaller countries within the group will have two to five years more to adapt to the open system.

JUNE 17. European Community ministers said they had agreed on a four-year $274 million subsidy to the broadcast industry in Europe, to help it air wide-screen television programs and kickstart a lucrative market for wide-format TV sets.

JUNE 17. Japan's **Fujitsu Ltd.** and **Siemens-Nixdorf Informationssysteme AG** of Germany said they would develop a new generation of mainframes to go on the market in 1996. The new computers would replace emitter-coupled logic with CMOS chips, which cost less and need no special cooling.

JUNE 18. Northern Telecom Ltd. of Canada announced an agreement with **China's State Planning Commission** to supply China with telecommunications, switching, and transmission equipment, advanced computer chips, training services, and a development laboratory for advanced gear. The pact is part of a project to bring phone service to China's one-billion-plus citizens, only 2 percent of whom have phones.

JUNE 21. The **U.S. Department of Commerce** announced it had revoked import duties on flat-panel active-matrix display screens manufactured outside the United States. The department said the 62.67 percent duties had outlived their usefulness and that the only U.S. company making such displays, **OIS Optical Imaging Systems Inc.,** Troy, MI, had requested the penalties be lifted.

JUNE 21. Hitachi Ltd., Tokyo, said it had developed a technique whereby light can be transmitted unweakened through optical ICs. The prototype integrates each end of an optical amplifier 500 μm long and 5 μm wide with a waveguide path of equal width and 1350 μm long.

JUNE 21. A report by the **World Bank** and **the International Energy Agency** said 25 of the most dangerous nuclear reactors located in six former Soviet bloc countries could be closed during the next few years and replaced with gas-fired power plants without paralyzing the countries' economies. The study, drawn up for the Group of Seven July summit meeting in Tokyo, estimates that $18 billion will be needed for the replacements in Russia, Ukraine, Armenia, Lithuania, Bulgaria, and Slovakia.

JUNE 22. Zenith Data Systems Corp., Buffalo Grove, IL, said it would acquire a 19.9 percent stake in **Packard Bell Electronics Inc.,** Chatsworth, CA, to design and manufacture desktop computers. The alliance gives Zenith Data, a unit of France's Groupe Bull, a presence in the mass merchandizing market, and provides Packard Bell with cash and new notebook and subnotebook products.

JUNE 24. The **U.S. House of Representatives** voted overwhelmingly to halt construction on the **superconducting supercollider,** the $11 billion, 90-km proton-smasher in Waxahachie, TX. Proponents of the supercollider said it was doubtful that the U.S. Senate could save the project, as it did last year.

JUNE 28. The **U.S. House of Representatives** voted to preserve financing for a smaller-scale **Space Station Freedom,** ensuring at least one more year of construction. The House amendment that would have killed the project was defeated by a single vote the week before. The slimmed-down space station will cost $10.5 billion over five years. To date the Government has spent $9 billion on the project.

JULY 1. Researchers at **IBM Corp.** demonstrated a blue-laser optical recording system that can read and write 0.4 billion bits per square centimeter, five times as much data as products using infrared lasers, which cannot be focused as tightly. At the new density, a double-sided 5.25-inch optical disc would hold 6.5 billion bytes of data.

JULY 5. Groupe Bull, France's state-controlled computer company, said that it would cut 6500 jobs worldwide by the end of next year. The cuts, representing 18 percent of Bull's year-end 1992 workforce of 35 175, would include voluntary departures, reassignments, and layoffs.

JULY 6. Apple Computer Inc., Cupertino, CA, confirmed that it would slice its workforce by 16 percent, or about 2500 employees worldwide, most of them during July. The company will also restructure its organization and cut executive salaries, some by 5 percent, effective immediately.

Preview:
AUG 14. This is the date two of Japan's satellite communications firms—**Japan Communications Satellite Co.** and **Satellite Japan Corp.**—will complete their merger. Analysts said the merger is due to a drop in Japan's communications satellite business, which has been far less than projected four years ago when companies competed to enter the field.

COORDINATOR: Sally Cahur

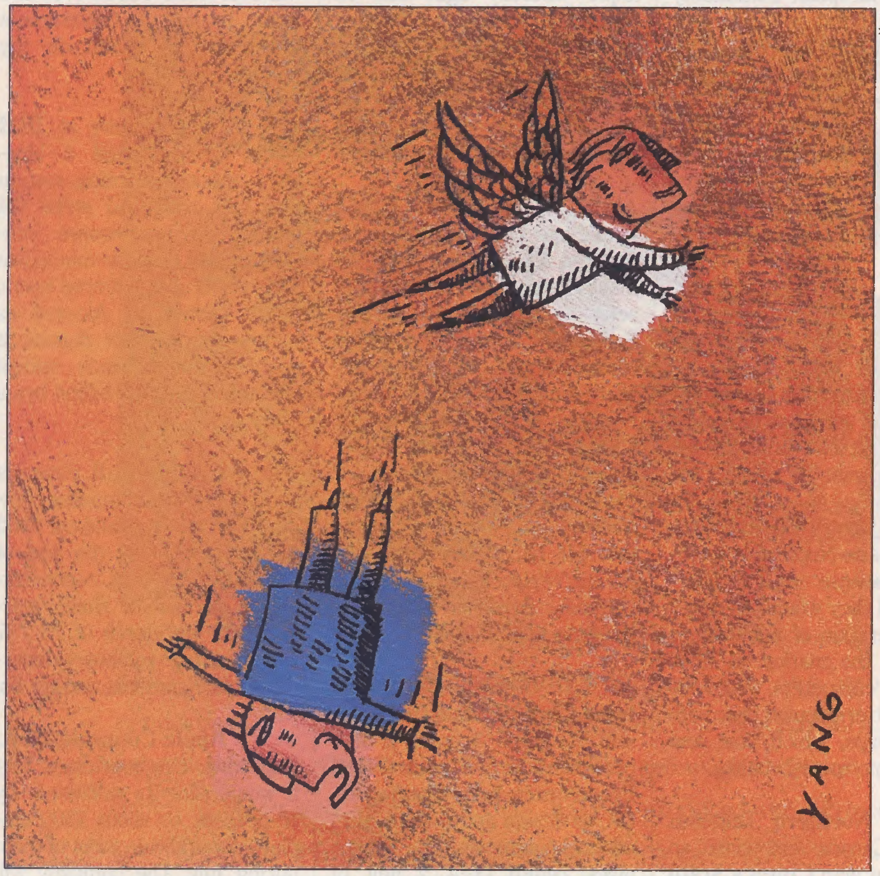
AUGUST 1993 Volume 30 Number 8

IEEE SPECTRUM

SPECIAL REPORT

18 JOBS AT RISK

By TRUDY E. BELL



The hundreds of thousands of jobs cut from major multinational companies in the last two years—leading to record-high unemployment among engineers around the world—are symptomatic of fundamental changes in the way high-tech companies will do business in the 21st century.

The causes include greater efficiencies provided by information technology and automation, the ending of the Cold War, and the desire of large companies to downsize and emulate the nimbleness of smaller ones. Thus, even once recovery is fully under way, many jobs will no longer exist. The overriding desideratum is to offer high-tech products and services that will compete in both quality and price in a stiff international market.

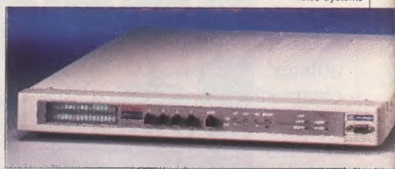
So how can you, the individual engineer, survive this turbulent world? This special report examines trends in engineering employment and highlights opportunities.

COMMUNICATIONS

36 Putting data on a diet

By JEFFREY WEISS and DOUG SCHREMP

Telco Systems



Knowing the basics of lossless data-compression is key to choosing a system that economizes on transmission line fees and storage requirements. This Telco Systems Optimizer recognizes and eliminates redundancies, compressing data by up to 6:1 (more typically, 3.5:1) at rates up to 7 MB/s.

APPLICATIONS

40 Mixing signals on chip

By LAUREN BRUST and MEAN-SEA TSAY

The growing demand for ever smaller personal communications and computing units, such as the AT&T EO 440 Personal Communicator below, requires ICs that combine analog and digital circuits at low power. While some basics carry over from 5-V digital design, low-voltage mixed signal circuits raise a new crop of issues for design, simulation, and test.

AT&T Consumer Products

MANAGEMENT

COMPANIES

AWARDS

Cover: Many engineers face an uncertain future as their companies grapple with the downsizing brought about by the end of the Cold War even while their countries are gripped by economic recession. In this conception by artist James Yang, those with jobs at risk find themselves as if at the edge of an abyss. Some who make themselves wings fly successfully into the future; others will not. See p. 18.

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Forum

Out of focus on fuzzy logic

Enrique Ruspini's account of our book *Fuzzy Logic* [June, pp. 11–15] is a mess. Indeed, for one who claims the mantle of authority, the jumble of errors is remarkable.

Intriguingly, Ruspini is not a disinterested reviewer. We interviewed him for the book, yet left him out of it.

Omitting him might seem ill-advised, since Ruspini tells readers of the review that he introduced fuzzy logic to pattern recognition in 1969. Actually, Lotfi Zadeh did so in 1965, in the famous paper that launched fuzzy logic ("Fuzzy Sets," *Information and Control*, June 8, 1965, pp. 338–53). Moreover, Richard Bellman, Robert Kalaba, and Zadeh wrote the first full journal article in 1966 ("Abstraction and Pattern Classification," *Journal of Mathematical Analysis and Applications* Vol. 13, January 1966, pp. 1–7). And in 1968 Zadeh brought fuzzy logic to a pattern recognition conference in Honolulu, where it caused a stir.

In fact, Ruspini's 1969 paper does not even use the rules of fuzzy logic. "Our rules of operation are not those proposed by Zadeh," he writes, "but those that come naturally from probability theory" ("A New Approach to Clustering," *Information and Control*, Vol. 15, 1969, pp. 22–32).

Errors likewise pervade Ruspini's analysis of our book. For instance, we discuss a logic of Jan Lukasiewicz that has three values: 0 (false), 1/2 (indeterminate), and 1 (true). For the crucial 1/2 value, we say that negation works as follows:

Statement: "It is possible that snow will fall tomorrow."

Negation: "It is possible that snow will not fall tomorrow."

"Actually," Ruspini tells the audience, "the negation is 'it is not possible that snow will fall tomorrow.' "

But Ruspini has not read Lukasiewicz. He assumes "possible" is modal, whereas in fact the Polish logician gives it a truth-functional sense. It reflects a degree to which "snow will fall tomorrow" is true ("On Three-Valued Logic," in L. Borkowski, ed., *Jan Lukasiewicz: Selected Works*, North-Holland, London, 1970, pp. 87–88). His mistake reveals a complete misunderstanding of this logic. If Ruspini were right, the Lukasiewicz construct would lose much of its interest and originality.

Ruspini scoffs at our "conceptual mix-ups" between statements and their truth-values. For instance, regarding the 1/2 value above, we say "STATEMENT = non-STATEMENT. Assertion and opposite are equivalent." Ruspini responds, "This is utterly absurd." But he himself is confused. The equal sign indicates logical equivalence, "if and only if" (for example, Robert R. Stoll, *Set Theory and Logic*, Dover, New York, 1963, p. 201). We do not say assertion and opposite are the same statement; we say they imply each other, as they clearly do.

The mistakes continue. Ruspini wonders why we criticize Aristotle. But if one insists on Aristotle's Law of Contradiction and Law of the Excluded Middle, partial membership in a set becomes logically impossible. Fuzzy logic becomes impossible. That is why.

Ruspini says we "seem to believe that the logical times have changed and that the logical errors of Aristotle have finally been surmounted." This charge is fantastic. He says he bases it on an epigraph in the book. No epigraph to this effect exists.

Ruspini says our book makes "preposterous claims" about sex robots and novel-writing machines. We make no such claims. We quote an expert speaking about the distant future, state that he may or may not be right, and warn the reader of the hazards of such forecasts (p. 242). And, as it happens, Birch Lane Press has just published a computer-written novel called *Just This Once* (Sarah Lyall, "Book Notes," *New York Times*, June 23, 1993, p. B4).

Ruspini also tries to impute to us such absurdities as: Aristotle's biographers are flaks, "the downfall of classical logic" caused the success of fuzzy logic, and yes/no thinking is useless.

This man has misled the readership.

Daniel McNeill
Culver City, CA
Paul Freiberger
San Mateo, CA

Relieving back pain

It was interesting to read about the application of lasers in medical science [January, pp. 76–79]. I would like to add that I have helped in the development of a new application of lasers in orthopedic surgery. The technique alleviates spinal nerve entrapment, a major source of low back pain. The resulting protrusion causes pain, numbness, or muscular weakness anywhere from the middle of the buttocks to the bottom of the foot.

At present, techniques commonly used to dissolve the central part of the spinal disc involve an enzyme, or removal by suction, or surgery. My technique, called laser percutaneous decompression, works on the principle (now called Ranu's Principle) that a small change in the volume of the disc tissue results in an exponential change in pressure.

The technique, administered under local anesthesia, involves inserting a needle into the central portion of the herniated disc. An optical waveguide is connected, then an Nd: YAG 1.32-μm laser is inserted into the needle. In between lasing, 1-second pauses are allowed for cooling until 800 to 1000 joules of energy have been delivered to the nucleus of the disc and the central portion has been vaporized. This small space allows the surrounding annulus fibrosus to regress and thus relieve pressure on the spinal cord. Needle and optical fiber are withdrawn, and a dry sterile dressing is applied to the patient's back.

The patient is discharged immediately, the entire procedure taking about 35 minutes, just 4 minutes of which is laser treatment or laser zapping time. Patients are told to limit their activity for the first four days, and thereafter full activity is allowed only if the patient has no pain.

This technique has relieved pain in 80 percent of patients tested so far for herniated lumbar spinal discs. Pressures inside the spinal disc are compared by a transducer, just over 1 mm in diameter, before, during, and immediately after completion of the laser surgery. It has been found that a drastic pressure reduction results.

The technique has been used on over 120 patients in the St. Luke's–Roosevelt Hospital Center, University Hospital at Columbia University College of Physicians and Surgeons, New York City.

Harcharan Singh Ranu
Greenvale, NY

Correction

On pp. 20 and 24 of the May issue, Fred Cohen should have been described as doing his work and Ph.D. thesis at the University of Southern California, Los Angeles. —*Ed.*

Readers are invited to comment in this department on material previously published in *IEEE Spectrum*; on the policies and operations of the IEEE; and on technical, economic, or social matters of interest to the electrical and electronics engineering profession. Short, concise letters are preferred. The Editor reserves the right to limit debate on controversial issues. Contact: Forum, *IEEE Spectrum*, 345 E. 47th St., New York, NY 10017, U.S.A.; fax, 212-705-7453. The computer bulletin board number is 212-705-7308; the password is SPECTRUM. The line parameters are 1200 bits per second, no parity, 8 data bits, and 1 stop bit. For more information, call 212-705-7305 and ask for the Author's Guide.

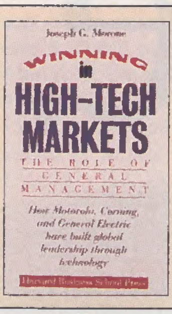
Books

High tech and top management

J.E. Goldman

The perennial polemic within the business education establishment pits the empiricists, the case-method enthusiasts, against the theorists, who prefer an analytical approach to establishing broad principles of management. Joseph Morone, in this remarkable book, comes down squarely on the side of the experiential approach, which he calls the behavioral school, as distinguished from the normative (his term for the analytical).

Winning in High Tech Markets: The Role of General Management.
Morone, Joseph G., Harvard Business School Press, 1992, 292 pp., $29.95.



Morone is an associate professor in the Rensselaer Polytechnic Institute's School of Management in Troy, NY, and has experience as a staff member in the General Electric Corporate Research and Development Laboratories. He has selected three cases of high-tech innovation by U.S. industry, tracked their history, and explored the reasons for their success in the face of the dismal record of innovation in large industry over the last three decades.

The three examples chosen are: General Electric Co.'s Medical Systems Division, which in roughly 20 years has achieved undisputed world leadership in the new medical diagnostic technologies of computerized tomography (CAT) scanning and magnetic resonance imaging (MRI); Motorola Inc., for its mastery of both the technology and marketing of portable communications; and Corning Inc., for notable technological advances that enabled the company to capture three new and completely unanticipated markets for its glass-based products—optical fibers for communications, glass surfaces for the growing flat-panel liquid-crystal–display market, and Celcor inner linings for automotive catalytic converters. All three of these companies took advantage of in-house technological capabilities to leapfrog the competition when the markets emerged.

Morone's approach is to seek the common denominators of these widely varying company cultures and technologies. And his conclusions are incontrovertible, supported by the evidence of failures in other companies that did not capitalize on technological leadership because one of a number of critical requisites was missing. Three such requisites stand out: the existence of a well-defined, consistent, and continuous corporate strategic focus supported from the top to the bottom of the managerial echelons; maintenance of continuity of both programs and people within the R&D establishment, even when the dictates of the marketplace are not readily apparent; and active understanding by top management of, and involvement in, the interplay between technology, marketing, and manufacturing.

It is no accident, according to Morone, that in all three successful instances the top management responsible came to their posts with a solid technical background. In contrast, the author cites case after case in which a company had the necessary ingredients and experience, but nonetheless failed to exploit its capabilities in a changing technical and market environment because of the predominance of financial planners in key decision-making positions.

"Decisions regarding investment, R&D spending, and new business development [in these three companies] are shaped by the imperative that the business remain a leader in its field," Morone writes. "The analytic, financially-driven style of decision making that is so much a part of American management culture is absent here. *Financial considerations are constraints on general management decision making rather than its determinants*" (italics mine). Morone's analysis brings to mind *The Reckoning*, David Halberstam's classic study of the automobile industry, wherein he ascribes the success of the Japanese automobile companies after World War II to the fact that they were managed by car people, not by the finance people who predominated at the U.S. firms.

Morone's research is exhaustive. He interviewed all the key players in all three companies, and he demonstrates a keen understanding of how the rest of industry responds to the same or comparable challenges. So deeply does he get into the mind-set of the decision-makers that the reader closes this book feeling almost on intimate terms with each of the players. Many books on the management of industrial technology have been published in the last dozen years but, in the opinion of this reviewer (who has reviewed many of them for this and other publications), none has hit the nail so squarely on the head as has this book. Moreover, the style and literary quality is so superior that the reader, however remote he or she may be from the day-to-day problems covered in this work, is kept in continuous suspense as if reading a mystery novel.

To be sure, there are some flaws, but they are minor. In tracking GE Medical Systems' road to preeminence in MRI diagnostics, only scant mention is made of the important role played by emergent smaller companies focusing on superconducting magnets (one company was itself a GE spin-off). These companies served a significant catalytic function, enhancing the timeliness with which GE was able to establish a leadership position in the sophisticated systems built around those magnets. Clearly, successful technical enterprises can capitalize on advances made by smaller satellites and often play midwife to the birth of such companies, if developing or supporting the technologies in-house appears counterproductive or cost-ineffective.

Another weakness is in the last chapter, "Implications for Government Policy," in which the author seeks to extrapolate his conclusions about the root causes of technological success in the private sector. I, frankly, could not find compelling connections between the author's sound conclusions on what makes a high-tech company successful and what government's role should be.

This question is being addressed seriously in the contemporary U.S. political context and deserves far more attentive analysis than a brief transference of experiences from one domain to a completely different one. The author's thorough researches may lead him to more intelligent conclusions than we have witnessed so far in the political process. Indeed, they may deserve a separate book or a more extensive analysis, but as a postscript to a superior book, they are found wanting.

Competitiveness in the manufacturing sector, job creation through new R&D initiatives, and reorientation of defense R&D in a post–Cold War world present a multidimensional matrix for government involvement—one that should not be trivialized as an afterthought.

J.E. Goldman is chairman and chief executive officer of Softstrip Inc., a Waterbury, CT, company that produces Softstrip, a print-based encoding system for computer-generated text, data, and graphics, and scanners for decoding. In 1983 he retired as senior vice president for R&D at Xerox Corp., where among other achievements he founded and supervised the company's Palo Alto Research Center. Before joining Xerox, he directed Ford Motor Co.'s Scientific Research Laboratory.

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uirements Analysis and *Sodhi, Jag,* McGraw-Hill, , 241 pp., $42.95.

the Los Angeles, San Francisco, or New York City of half a century ago is replaced with modern-day Silicon Valley. Seedy bars, coffeehouses, and cheap motels give ground to central offices, technical assis-

encyclopedia devoted to the subject area of interest.

With 690 articles collected from the larger set, the *McGraw-Hill Encyclopedia of Engineering* covers 11 different engi-

Design. *Wilkinson, Barry, et al.*, Prentice Hall/Simon & Schuster, New York, 1992, 538 pp., $53.40.

C++ and the OOP Paradigm. *Rao, B. R.*, McGraw-Hill, New York, 1993, 188 pp., $39.95.

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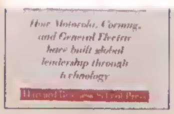

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Morone's approach is to seek the common denominators of these widely varying company cultures and technologies. And his conclusions are incontrovertible, supported by the evidence of failures in other

which a company had the necessary ingredients and experience, but nonetheless failed to exploit its capabilities in a changing technical and market environment because of the predominance of financial planners in key decision-making positions.

"Decisions regarding investment, R&D spending, and new business development [in these three companies] are shaped by the imperative that the business remain a leader in its field," Morone writes. "The analytic, financially-driven style of decision making that is so much a part of American management culture is absent here. *Financial considerations are constraints on general management decision making rather than its determinants*" (italics mine). Morone's analysis brings to mind *The Reckoning*, David Halberstam's classic study of the automobile industry, wherein he ascribes the success of the Japanese automobile companies after World War II to the fact that they were managed by car people, not by the finance people who predominated at the U.S. firms.

Morone's research is exhaustive. He interviewed all the key players in all three companies, and he demonstrates a keen understanding of how the rest of industry responds to the same or comparable challenges. So deeply does he get into the mind-set of the decision-makers that the reader closes this book feeling almost on intimate terms with each of the players. Many books on the management of industrial technology have been published in the last dozen years but, in the opinion of this reviewer (who has reviewed many of them for this and other publications), none has hit the nail so squarely on the head as has this book. Moreover, the style and literary quality is so superior that the reader, how-

ing the technologies in-house appears counterproductive or cost-ineffective.

Another weakness is in the last chapter, "Implications for Government Policy," in which the author seeks to extrapolate his conclusions about the root causes of technological success in the private sector. I, frankly, could not find compelling connections between the author's sound conclusions on what makes a high-tech company successful and what government's role should be.

This question is being addressed seriously in the contemporary U.S. political context and deserves far more attentive analysis than a brief transference of experiences from one domain to a completely different one. The author's thorough researches may lead him to more intelligent conclusions than we have witnessed so far in the political process. Indeed, they may deserve a separate book or a more extensive analysis, but as a postscript to a superior book, they are found wanting.

Competitiveness in the manufacturing sector, job creation through new R&D initiatives, and reorientation of defense R&D in a post–Cold War world present a multidimensional matrix for government involvement—one that should not be trivialized as an afterthought.

J.E. Goldman is chairman and chief executive officer of Softstrip Inc., a Waterbury, CT, company that produces Softstrip, a print-based encoding system for computer-generated text, data, and graphics, and scanners for decoding. In 1983 he retired as senior vice president for R&D at Xerox Corp., where among other achievements he founded and supervised the company's Palo Alto Research Center. Before joining Xerox, he directed Ford Motor Co.'s Scientific Research Laboratory.

In brief

Interrupt. *Dwiggins, Toni, TorBooks, New York, 1993, 317 pp., $19.95.*

Meet Interrupt: computer criminal, telecommunications expert, terrorist, murderer, and electrical engineer. EEs should not be offended by such an unflattering portrait in this self-described "techno-mystery," however; the hero, Andy Faulkner, is also an engineer. Brilliant, earnest, and emotionally conflicted, Faulkner may be the most entertaining acrophobe since Jimmy Stewart in *Vertigo*.

Faulkner and Interrupt are not the only engineers in this fast-moving thriller. In fact, almost all of its characters are engineers, a notable exception being the beautiful, golden-haired love interest, who of course is a lineman (not a line*person*, she insists).

Telecommunications specialists may recognize an unusual degree of realism, and perhaps even accuracy, thanks to author Dwiggins' tireless research into telephony.

Mystery fans will recognize all the elements standard to that genre, except that the Los Angeles, San Francisco, or New York City of half a century ago is replaced with modern-day Silicon Valley. Seedy bars, coffeehouses, and cheap motels give ground to central offices, technical assistance centers, and, well, cheap motels (some things never change, it seems). After reading Dwiggins' account of one tender encounter, telco employees may never feel the same about the inside of a utility van. Enough said.

On the book's jacket, comparisons are made with Tom Clancy, which are inevitable but probably unwarranted. Dwiggins writes smoothly and her characters are lifelike. Technical details are woven into the plot and support it; they are not its flimsy *raison d'être*.

McGraw-Hill Encyclopedia of Engineering, 2nd Edition. *Ed. Parker, Sybil P., McGraw-Hill, New York, 1993, 1414 pages, $95.50.*

The 20-volume, $1900 *McGraw-Hill Encyclopedia of Science and Technology* is unmatched in scope and authority. But for some it may be a tad too, well, encyclopedic, and perhaps beyond the budget as well. However, anyone whose interests are mainly in engineering, chemistry, environmental science, physics, or astronomy has an economical alternative: a one-volume encyclopedia devoted to the subject area of interest.

With 690 articles collected from the larger set, the *McGraw-Hill Encyclopedia of Engineering* covers 11 different engineering disciplines, including electrical, nuclear, and power engineering. Various articles are tutorial, synoptic, or historical in tone. There are hundreds of diagrams, drawings, and photographs, many of the latter of apparent unintended nostalgic as well as illustrative value.

Contact McGraw-Hill Professional Book Group, 11 West 19th St., New York, NY 10011; 212-337-5945; or, to order, 800-262-4729.

COORDINATOR: Glenn Zorpette

Recent books

'91 EOS Transactions, Vol. 72, nos. 27–53. *American Geophysical Union*, Washington, DC, 1991, 200 pp., $190 (annual subscription).

Software Requirements Analysis and Specification. *Sodhi, Jag,* McGraw-Hill, New York, 1992, 241 pp., $42.95.

Digital System Design. *Wilkinson, Barry, et al.*, Prentice Hall/Simon & Schuster, New York, 1992, 538 pp., $53.40.

C++ and the OOP Paradigm. *Rao, B. R.*, McGraw-Hill, New York, 1993, 188 pp., $39.95.

Recent books

Reality Rules: I Picturing the World in Mathematics—The Fundamentals. Reality Rules: II Picturing the World in Mathematics—The Frontier. *Casti, John L.*, John Wiley & Sons, New York, 1992, 388 pp. and 424 pp., $39.95 and $44.95, respectively.

Distributed Databases, Cooperative Processing, & Networking. *Atre, Shaku*, McGraw-Hill, New York, 1992, 256 pp., $49.95.

Atoms in Intense Laser Fields. Ed. *Gavrila, Mihai*, Academic Press, San Diego, CA, 1992, 516 pp., $89.95.

Independent Verification & Validation. *Lewis, Robert O.*, John Wiley & Sons, New York, 1992, 356 pp., $59.95.

3D Autocad for Architects and Engineers, revised 1st edition. *Johnson, Frank J.*, McGraw-Hill, New York, 1992, 269 pp., $24.95.

Statistical Intervals: A Guide For Practitioners. *Hahn, Gerald J.*, and *Meeker, William Q.*, John Wiley & Sons, Somerset, NJ, 1992, 392 pp., $54.95.

The Role of Microscopy in Semiconductor Failure Analysis. *Richards, B.P.*, and *Footner, P.K.*, Oxford University Press, New York, 1992, 108 pp., $27.50.

Multivariate Density Estimation: Theory, Practice, and Visualization. *Scott, David W.*, John Wiley & Sons, New York, 1992, 316 pp., $59.95.

Japan's Growing Technological Capability: Implications for the U.S. Economy. Eds. *Arrison, Thomas S., et al.*, National Academy Press, Washington, DC, 1992, 235 pp., $30.

A First Course in Order Statistics. *Arnold, Barry C., et al.*, John Wiley & Sons, New York, 1992, 279 pp., $49.95.

Ecolinking: Everyone's Guide to Online Environmental Information. *Rittner, Don*, Peachpit Press, Berkeley, CA, 1992, 352 pp., $18.95.

Power Electronics: Devices, Drivers, Applications, and Passive Components, 2nd edition. *Williams, B.W.*, McGraw-Hill, New York, 1992, 542 pp., $59.95.

Independent Verification & Validation: A Life Cycle Engineering Process for Quality Software. *Lewis, Robert O.*, John Wiley & Sons, New York, 1992, 356 pp., $59.95.

Applied Digital Control: Theory, Design & Implementation, 2nd edition. *Leigh, J.R.*, Prentice Hall, Englewood Cliffs, NJ, 1992, 524 pp., $48.

Power System Relaying. *Horowitz, Stanley H.*, and *Phadke, Arun G.*, John Wiley & Sons, New York, 1992, 281 pp., $59.95.

Ultrafast Processes in Spectroscopy 1991. Eds. *Laubereau, A.*, and *Seilmeier, A.*, American Institute of Physics, New York, 1992, 650 pp., $136.

America Calling: A Social History of the Telephone to 1940. *Fischer, Claude S.*, University of California Press, Berkeley, CA, 1992, 439 pp., $25.

Process Innovation: Reengineering Work through Information Technology. *Davenport, Thomas*, Harvard Business School Press, Boston, 1992, 326 pp., $29.95.

Environmental Information. *Rittner, Don*, Peachpit Press, Berkeley, CA, 1992, 352 pp., $18.95

Do-It Yourself Visual Basic for MS-DOS. *Orvis*, William J., SAMS/Prentice Hall, Carmel, IN, 1992, 818 pp., $27.95.

Calendar

AUGUST

36th Midwest Symposium on Circuits and Systems (CAS, CS, et al.); Aug. 14–17; Westin Hotel Renaissance Center, Detroit, MI; Michael P. Polis, Department of Electrical and Computer Engineering, Wayne State University, Detroit, MI 48202; 313-577-3920.

Second International School and Topical Meeting on Applications of Nonlinear Optics (LEOS); Aug. 16–20; Russian Academy of Sciences and Czech Technical University, Prague, Czech Republic; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855-1331; 908-562-3893.

International Geoscience and Remote Sensing Symposium (GRS); Aug. 18–21; Kogakula University, Tokyo; Mikio Takagi, Institute of Industrial Science, University of Tokyo, 7-22-1 Roppongi Minato-ku, Tokyo 106, Japan; (81+3) 3479 0289.

Eighth International Symposium on Intelligent Control (CS); Aug. 25–27; Knickerbocker Hotel, Chicago; Panos J. Antsaklis, Department of Electrical Engineering, University of Notre Dame, Notre Dame, IN 46556; 219-613-5792; fax, 219-631-8007.

International Conference on the Applications of Diamond Films and Related Materials (ED); Aug. 25–27; Sonic City Hall, Omiya Saitama, Japan; ADC '93 Secretariat, International Communications Inc., Kasho Building 2-14-9 Nihombashi, Chuo-ku, Tokyo 103, Japan; fax, (81+03) 3273 2445.

Solid State Circuits and Technology Workshop on Low-Power Electronics (SSC); Aug. 25–27; Biltmore Hotel, Phoenix, AZ; Ran-Hong Yan, AT&T Bell Laboratories, Holmdel, NJ 07733; 908-949-7695; fax, 908-949-6010; or Bob Nielsen, Eastman Kodak Co., Eastman Kodak Research Laboratory, Rochester, NY 14650-2024; fax, 716-477-4947.

International Conference on Solid-State Devices and Materials (ED); Aug. 29–Sept. 1; Nippon Convention Center, Chiba City, Japan; SS DM Secretariat, c/o Business Center for Academic Societies Japan, Honkomagome 5-16-9, Bunkyo-ku, Tokyo 113, Japan; (81+3) 5814 5800; fax, (81+3) 5814 5823.

International Symposium on Gallium Arsenide and Related Compounds (ED); Aug. 29–Sept. 2; Karlsbau Congress Center, Freiburg, Germany; Hans J. Boehnel, Fraunhofer Institut für Angewandte Festkorperphysik, Tullastrasse 72, W-7800 Freiburg, Germany; fax, (49+76) 1615 9400.

SEPTEMBER

Fourth European Conference on Electron and Optical Beam Testing of Electronic Devices (R); Sept. 1–3; Swiss Federal Institute of Technology (ETH), Zurich; Mauro Ciappo, Reliability Labor-

Calendar

atory, ETH-Zentrum, CH-8092 Zurich, Switzerland; (41+1) 256 2436; fax, (41+1) 251 2172.

Athens Power Tech—Planning, Operation and Control in Today's Electric Power Systems (PE, Greece Section); Sept. 5–7; Athens Concert Hall, Greece; B.C. Papadias, National Technical University of Athens, Electric Energy Systems Laboratory, Patission St. 42, Athens 106 82, Greece; (30+1) 360 0551 or 361 1983.

Computers in Cardiology Conference (EMB); Sept. 5–8; Imperial College of Science, Technology and Medicine, London; Richard Kitney, Centre for Biological and Medical Studies, Imperial College, Exhibition Road, London SW7 2BT, United Kingdom; (44+71) 225 8525; fax, (44+71) 584 6897.

Workshop on Neural Networks for Signal Processing (SP); Sept. 6–9; Maritime Institute of Technology and Graduate Studies, Linthicum Heights, MD; Gary Kuhn, Siemens Corporate Research, 755 College Rd., East, Princeton, NJ 08540; or Barbara Yoon, ARPA-IST, Wilson Boulevard, Washington, DC 20002.

Fifth Conference on Optical Hybrid Access Networks (COM, Region 7); Sept. 7–9; Four Seasons Hotel, Montreal; Raymond Quintal, 700 de La Gauchetière West, 18W2, Montreal, PQ, H3B 4L1, Canada; 514-870-3060; fax, 514-870-9560.

Fifth International Conference on Simulation of Semiconductor Devices and Processes (ED); Sept. 7–9; Technical University of Vienna, Austria; Siegfried Selberherr, Institute of Microelectronics, Gusshausstrasse 27-29/E360, A-1040 Vienna, Austria; (43+1) 58801 3855; fax, (43+1) 5059224.

Fourth International Symposium on Personal, Indoor and Mobile Radio Communications—PIMRC '93 (COM); Sept. 9–11; Pacifico Yokohama Convention Center, Yokohama, Japan; Shuzo Kato, NTT Radio Communications Systems Laboratories, 1-2356 Take, Yokosuka, 238-03 Japan; (81+46) 859 3470; fax, (81+46) 859 8022.

Sixth International Conference on Transmission and Distribution Construction and Live-Line Maintenance (PE); Sept. 12–17; Riviera Hotel and Casino, Las Vegas, NV; Ed Cromer, Nevada Power, MS90A, Box 230, Las Vegas, NV 89151; 702-657-4001; fax, 702-657-4036.

Magnetic Recording Conference (MAG); Sept. 13–15; University of Minneapolis, MN; Mardi Geredes, IIST, Santa Clara University, Santa Clara, CA 95053; 408-554-6853; fax, 408-554-5474.

Petroleum and Chemical Industry Technical Conference—PCIC '93 (IA, St. Louis/C); Sept. 13–15; Clarion Hotel, St. Louis, MO; Harold B. Dygert, Clark, Richardson & Biskup, 655 Craig Rd., Suite 240, St. Louis, MS 63141; 314-997-1515; fax, 314-997-6117.

IEEE members attend more than 5000 IEEE professional meetings, conferences, and conventions held throughout the world each year. For more information on any meeting in this guide, write or call the listed meeting contact. Information is also available from: Conference Services Department, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, NJ 80055; 908-562-3878; submit conferences for listing to: Ramona Foster, *IEEE Spectrum*, 345 E. 47th St., New York, NY 10017; 212-705-7305.

For additional information on hotels, conference centers, and travel services, see the Reader Service Card.

Software reviews

Plotting made easy

Erik Cheever

EasyPlot, *version 2, by Spiral Software, for viewing, analyzing, and plotting scientific data. Requires at least 2 MB of RAM. Runs on any PC that runs Windows. The software can (but need not) use a coprocessor. US $399.*

EasyPlot, version 2, is a software package from Spiral Software for analyzing and plotting scientific data. The program, which is an update of a DOS version, will run in either DOS or Windows. The Windows interface can be modified to resemble that of the DOS program, easing the transition from DOS for users of version 1.

The program is so easy to use that one can skip reading the user's manual and start drawing graphs straightaway. Data can be entered from a file, keyed into an integrated spreadsheet, or simply cut and pasted from another Windows application. Changing the marks used to represent a set of data is done simply by double-clicking on the data set in the graph. Changes to an axis are made by double-clicking on it. These options can also be altered by navigating through the menus. The wide variety of graphs possible includes standard two-dimensional plots, semi-log, log-log, and polar plots. Three-dimensional data may be displayed as a contour or else as a mesh plot that can be viewed from any angle, and can even be animated as it rotates.

In addition to its plotting capabilities, EasyPlot can do many types of analyses, including curve fitting (to arbitrary functions), splines, smoothing, rudimentary statistics, and Fourier transforms.

Some of EasyPlot's features are lacking in other plotting packages. There are cross-hairs to read *x-y* coordinates from a graph for sending to a file. A powerful batch language is available to display, process, and print large quantities of data automatically, saving the user much time otherwise spent in front of the computer repetitively typing commands.

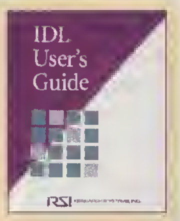
EasyPlot is a full-featured, powerful package that is reasonably priced. Yet despite its capabilities, it occupies only slightly more than half of a megabyte of disk space, a truly remarkable achievement. *Contact: Spiral Software, 15 Auburn Place, Brookline, MA 02146; 617-739-1511; fax, 617-739-4836; or* **circle 100.**

Erik Cheever (M) is associate professor of engineering at Swarthmore College in Pennsylvania.

Graphical analysis in Windows

John L. Schmalzel

Interactive Data Language (IDL) for Windows takes powerful analysis and display capabilities from Unix- and VMS-based workstations and extends them to the PC environment. The product is well-suited to a broad spectrum of general scientific and engineering uses. Anyone already familiar with IDL on a workstation will find that version 3.0 has added graphical object support for display and user control using widgets—built-in graphical interface tools.



IDL for Windows, *software for interactive analysis and visualization of scientific and engineering data. For PCs operating under Windows, requires 8-MB RAM and 12-MB hard disk. US $1500.*

Configurations recommended in the installation guide include a 386 (with a 387) or 486-based PC with at least 8 MB of memory. Microsoft Windows 3.1 or higher is a necessity. No disk space requirement is given; however, my installation consumed 9.2 MB on a Zeos 486-33 system.

IDL is user friendly in that extensive online help is provided on topics for each of its three libraries—statistics, user, and widget. Because I was a first-time user, I worked through the tutorial manual, which took about 12 hours. It was a worthwhile investment because it let me preview a broad cross section of IDL's capabilities.

Principal access to IDL is through a command line window. Functions are executed interactively with the results immediately printed or plotted. This allows IDL to be used as a "super calculator" for solving problems involving not too many steps. However, the most effective way to put IDL to work is by writing procedure scripts. Complex procedures that incorporate the full range of intrinsic IDL functions can be written using a structured-language syntax loosely based on APL. In combination with widgets for input and output, users can build complex, interactive applications like image processing with user control of filtering parameters along with a simultaneous display of results. Those accustomed to writing analysis programs in any high-level language will find the development of IDL procedures to be fairly straightforward. A number of working examples are provided, and the procedure template provided with IDL encourages a standardized format.

IDL has an impressive number of functions available, and many perform very complex operations. One feature of the language that deserves special mention is its support of seven types of widget. One handles organization, serving as a host; three provide variations of text support; two provide button and slider inputs that mimic familiar switch and potentiometer imputs; and the last provides the graphics interface.

Another of IDL's assets is its animation support. With the Xinteranimate function, sequences of images and other graphical output can be constructed, then played forward and backward at variable rates.

In sum, IDL is a powerful product offering sufficient resources for many challenging applications. Users looking for specific functions are likely to be disappointed, at least until this product has been in use for some time. Similarly, data acquisition support would be a logical extension of IDL's scope and evolution. *Contact: Research Systems Inc., 777 29th St., Suite 302, Boulder, CO 80303; 303-786-9900; fax, 303-786-9909; or* **circle 101.**

John L. Schmalzel (M) is an associate professor of electrical engineering in the division of engineering at the University of Texas at San Antonio.

COORDINATOR: Gadi Kaplan

Recent software

Timing Designer V1.3. For specifying timing requirements. US $1295 (Microsoft PC); $2495 (Unix workstation). *Contact: Chronology Corp., 2721 152nd Ave., N.E., Redmond, WA 98052-5516; 206-869-4227; fax, 206-869-4229; or* **circle 102.**

Spyglass Transform 3.0, a visual data analysis and presentation tool. US $995 (Unix); $595 (Mac). *Contact: Spyglass Inc., 1800 Woodfield Dr., Savoy, IL 61874; 217-355-6000; fax, 217-355-8925; or* **circle 103.**

Speakout

Pharaoh, Luther, and R&D today

Research has evolved into a process in which many people are paid for doing things of no value. Or, stated another way, many researchers deliberately do things of no value in order to get paid. In this respect, they have become the world's ultimate bureaucrats. They have become paper-pushers.

Doing things of no value means choosing the research subject with the intent of generating a paper, not of producing an answer. Generating a paper leads to approbation, tenure, and a lifetime job and money. The paper is the ultimate hubris, like Achilles sitting in his tent sulking and dreaming about the beautiful princess he was denied. While the Greeks needed answers, namely Trojan scalps, Achilles fantasized. While the nation needs answers, how-to-do-it manuals, and hardware embodiments, the scientists sit in their ivory towers producing papers in paroxysms of mental masturbation akin to Achilles and the untouchable princess.

But might the paper be of value? Perhaps, but so what? The work within it was done because the scientist wanted to produce a paper, because the problem was tractable, because funding was available, or because the concept of tenure weighs publications by the pound or counts them by the dozen. (I heard an administrator once say he didn't care about the quality of the 17 papers a colleague added to his bibliography one year, but rather he valued the large integer "17.")

So, is the content of the paper of value? Perhaps, but so what? As T.S. Eliot said in *Murder in the Cathedral*, Part 1, "The last temptation is the greatest treason:/To do the right deed for the wrong reason." The scientific paper is produced for all the wrong reasons, so its accidental value is of no consequence in the ethical scheme of things.

Why do I say ethical, since the scientist is following all the tenets of his profession, teaching well, publishing to get tenure, bringing in government money to support his salary and pay graduate students, and so on? Precisely because the whole process, other than teaching, has become unethical relative to the ancient standards of academia.

Prior to World War II, universities paid an academic a full-time salary, gave him a half-time teaching load, and turned him loose half-time to do research on topics he deemed valuable. The university would furnish research equipment and expendables. Salary, expenses, and capital came from revenue from invested endowments (or from legislatures, for state universities). The significance of the research was judged by the academic's peers. Publication of one significant paper per year was deemed good output. Tenure came from this sort of track record.

The free half of his time to "do his own thing" was the scientist's assurance of academic freedom, guaranteed by the university. The freedom to do research, whether it was hard science or ancient ecclesiastics, was revered in academia way back in Martin Luther's time when the Duke of Saxony defended Luther's academic freedom at the University of Wittenberg from Roman domination in 1517.

Now, however, the complexion of academia has changed. The academic must bring in money for the half of his time devoted to research, for his equipment and expendables, and for his assistants. The universities have abdicated their old ethical role of keeping academic freedom alive by accepting the new routine of government proposals and contracts. Government functionaries now judge the works and award the rewards. Pharaoh owns all the grain, so to speak.

The academics are like Pavlov's dog, salivating at the ringing of the feeder's bell. (The feeder is the contract monitor.) One is reminded more of children running after the tinkling bell of the ice cream vendor than of astute intellectuals convening to discuss something of real value.

The ethics are changed because the process of choice is biased toward what is currently being funded. The academic cannot choose what he believes to be more valuable. He bares his soul in advance and asks a committee or a set of peers or a bureaucrat to judge whether he should be allowed to think along a certain line. He begs for his crust whereas the whole loaf was his right, once upon a time. Ethics is out the window since the existence of ethics presupposes the right and ability to choose. Academic freedom is hanging from the window ledge by her fingernails, and the jackboot is coming down.

Even the best of our talent is mute in her defense. When has anyone heard advocacy for the refusal of all government contracts? When has anyone advocated that the government give gigantic endowments to the universities, no strings attached, so that the universities could use the revenues therefrom to get back to the time-honored custom of salaried half-time for research as well as salaried half-time for teaching? Don't be silly, you say? Who is silly?

The year 1945, that watershed of change when the government decided to maintain its wartime dependence upon university scientists, is so long ago that the true academic freedom of research scientists is relegated to the oral history of old men (and some women) sharing reminiscences at a 50th college reunion. One has to go that far back to remember taking a job where the dean offered half-time teaching and half-time research without some involvement with government funding and quarterly reports. Anyone seeking tenure back then, say at age 25 in the year '45, is now past 70 and surely retired. Although the subject is not so romantic, one could take a line from *Paul Revere's Ride* by Longfellow and write, "T'was the eighth of August, in Forty-five;/Hardly a man is now alive/Who remembers that famous day and year..." and not be far wrong if one is remembering the honest performance of research.

I don't remember it, but I know it vividly second-hand because my father didn't leave his work at the university. It came home with him. All his fears, all his aspirations, all his philosophizing, all his fights with deans and editors and referees...all these things came home. His fears of changing jobs were my fears because unemployment could be visualized by a Depression baby as no bed and no food. His whole family was party to his negotiations on half-time research as he changed venue in 1946. He is long gone, and I at 56 am already into the question of the oral history of the changing times and the degradation of ethics. Today, the Duke of Saxony would simply have let Martin Luther starve to death for all the support genuine academic freedom has.

Manny Parsonson

"Manny Parsonson" is the pseudonym of an industrial scientist with more than 20 years' experience directing groups of scientists and engineers solving customer-oriented problems in quality, productivity, instrumentation, and nondestructive testing. He has requested anonymity because, while he feels his message is "true and relevant for our times," he fears that its appearance under his own name could be harmful to his career.

Calendar

(Continued from p. 14)

International Conference on Control and Applications (CS); Sept. 13–16; Le Meridien Vancouver Hotel, Vancouver, BC, Canada; Guy Dumont, Pulp & Paper Center–UBC, 2385 E. Mall, Vancouver, BC V6P 1Z4, Canada; 604-822-8564; fax, 604-822-8563.

Software Engineering Standards Symposium (C); Sept. 13–17; Hospitality Inn, Brighton, United Kingdom; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1903; 202-371-1013; fax, 202-728-0884.

Virtual Reality Annual International Symposium (NN); Sept. 18–23; Sheraton Hotel, Seattle, WA; Thomas Caudell, Boeing Computer Services, Boeing Building 33-07, MS 7L-22, 2760 160 Ave., S.E., Bellevue, WA 98008; 206-865-3763.

International Symposium on Semiconductor Manufacturing (ED); Sept. 20–21; Austin Marriott Hotel at the Capital, Austin, TX; Steven Leeke, Texas Instruments Inc., MS 457, Box 655012, Dallas, TX 75265; 214-995-2249; fax, 214-995-1724.

Autotestcon '93 (AES et al.); Sept. 20–23; San Antonio Convention Center, San Antonio, TX; Robert E. Noble, 2500 Fallbrook, TX 78232; 512-491-0311.

15th International Congress on Instrumentation in Aerospace Simulation Facilities—ICIASF '93 (AES); Sept. 20–23; Institute at Saint-Louis, Saint-Louis Cedex, France; Hans J. Pfeifer, French-German Research Institute (ISL), 5 rue de l'Industrie, B.P. 34, F68301 Saint Louis Cedex, France; (33+89) 69 51 60; fax, (33+89) 69 51 62.

Second Network Management and Control Workshop (C); Sept. 21–23; Westchester Marriott Hotel, Tarrytown, NY; Judy Keller, IEEE Communications Society, 345 East 47th St., New York, NY 10017; 212-705-7365; fax, 212-705-7865.

43rd Annual Broadcast Symposium (BT); Sept. 22–23; Hotel Washington, Washington, DC; Edmund Williams, PBS, Engineering Department, 1320 Braddock Place, Alexandria, VA 22314; 703-739-5172.

15th Annual Electrical Overstress/Electrostatic Discharge Symposium—EOS/ESD (CHMT); Sept. 26–27; Buena Vista Palace, Lake Buena Vista, FL; EOS/ESD Association Inc., 200 Liberty Plaza, Rome, NY 13440; 315-339-6937.

Holm Conference on Electrical Contacts (CHMT); Sept. 26–29; Pittsburgh Vista, Pittsburgh; Holm Conference Registrar, IEEE Technical Activities, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855-1331; 908-562-3895; fax, 908-562-1571.

Third International Workshop on Photonic Networks, Components, and Applications (LEO, COM); Sept. 26–29; Westin Peachtree Plaza, Atlanta, GA; Kathy Mahoney, Conference Registrar, Photonics '93, 340 March Rd., Suite 400, Kanata, ON, K2K 2E4 Canada; 613-592-8160; fax, 613-592-8163.

Second International Workshop on Emerging Technologies and Factory Automation—ETFA '93 (IE et al.); Sept. 27–29; Palm Cove Resort, North Queensland, Australia; Alfred C. Weaver, Department of Computer Science, Thornton Hall, University of Virginia, Charlottesville, VA 22903; 804-982-2201.

International Symposium on Subscriber Loops and Services (COM); Sept. 27–Oct. 1; Vancouver Trade & Convention Center, Vancouver, BC, Canada; Shahid Hussain, BC Tel, 2-4535 Canada Way, Burnaby, BC, V5G 1J9, Canada; 604-654-7420; fax, 604-654-7447.

Sixth Annual International ASIC Conference and Exhibit (Rochester Section, C); Sept. 27–Oct. 1; Rochester Riverside Convention Center, Rochester, NY; Lynne M. Engelbrecht, 1806 Lyell Ave., Rochester, NY 14606; 716-254-2350; fax, 716-254-2237.

Wescon '93 (Bay Area C, LA Council); Sept. 28–30; Moscone Convention Center, San Francisco; Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, CA 90045-3194; 800-877-2668.

OCTOBER

International Conference on Computer Design: VLSI in Computers and Processors (ED); Oct. 3–6; Royal Sonesta Hotel, Cambridge, MA; IEEE Computer Society, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1903; 202-371-1013; fax, 202-728-0884.

Industry Application Society Annual Meeting (IA); Oct. 3–8; Royal York Hotel, Toronto; Ajit Bapat, Federal Pioneer Ltd., 19 Waterman Ave., Toronto, ON, M4B 1Y2, Canada; 416-752-8020; fax, 416-752-6230.

Bipolar/BiCMOS Circuits and Technology Meeting (ED); Oct. 4–5; Minneapolis Marriott City Center Hotel,

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Minneapolis, MN; John Shier, VTC Inc., 2800 E. Old Shakopee, Bloomington, MN 55425; 612-853-3292; fax, 612-853-3355.

15th International Electronic Manufacturing Technology Symposium (CHMT); Oct. 4–6; Marriott Hotel, Santa Clara, CA; Al Blodgett, IBM, 1580 Route 52, Hopewell Junction, NY 12533; 914-894-5018; fax, 914-894-3081.

Electrical/Electronics Insulation Conference (DEI); Oct. 4–7; Rosemont Convention Center, Chicago; Frank McGuinn, Box 35395, Minneapolis, MN 55439; 612-942-7388; fax, 612-942-7389.

International Conference on Semiconductor Electronics (ED); Oct. 5–7; Kuala Lumpur Hilton, Kuala Lumpur, Malaysia; Zahari M. Darus, Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia; (60+3) 825 1292.

International SOI Conference (ED): Oct. 5–7; Autry Resort, Palm Springs, CA; John Schott, USAF RADC/ESR, Hanscom AFB, MA 01731; 617-377-3817.

International Professional Communication Conference—IPCC '93 (PC); Oct. 6–8; Hotel Atop The Bellevue, Philadelphia; Michael B. Goodman, Fairleigh Dickinson University, Madison, NJ 07940; 201-593-8709; fax, 201-593-8510.

Gallium Arsenide Reliability Workshop (ED); Oct. 10; Fairmont Hotel, San Jose, CA; Anthony Immorlica, General Electric Co., Electronics Park 3-102, Syracuse, NY 13221; 315-456-3514; fax, 315-456-0695.

GaAs IC Symposium (ED); Oct. 10–13; Fairmont Hotel, San Jose, CA; Paul R. Jay, Bell-Northern Research, Box 3511, Station C, 3500 Carling Ave., 5C20 Ottawa, ON, K1Y 4H7, Canada; 613-763-2363.

Military Communications Conference—Milcom '93 (COM, Boston Section); Oct. 11–14; Stouffer Bedford Glen Hotel, Bedford, MA; Anthony A. Rutti, GTE Government Systems Corp., 77 "A" St., Building 23, Needham Heights, MA 02194; 617-455-4805; fax, 617-455-5734.

15th Symposium on Fusion Engineering (NPS); Oct. 11–15; Tara Hyannis Hotel & Resort, Hyannis, MA; Dori Barnes, Conference Publicity, Princeton Plasma Physics Laboratory, Box 451, Princeton, NJ 08543; 609-243-2557; fax, 609-243-3086.

Vehicle Navigation and Information Systems Conference (AES, VT, et al.); Oct. 12–14; Ottawa Congress Centre, Ottawa, Canada; D. Hugh M. Reekie, VNIS '93, Box 3083, Station D, Ottawa, ON, K1P 6H7, Canada.

International Conference on Universal Personal Communications (COM et al.); Oct. 12–15; Westin Hotel, Ottawa, Canada; Vino Vinodrai, Bell Mobility Cellular, 20 Carlson Court, Etobicoke, ON, M9W 6V4, Canada; 416-798-5039; fax, 416-674-6211.

International Workshop on Rough Sets and Knowledge Discovery (Region 7); Oct. 12–15; High Country Inn, Banff, AL, Canada; Wojciech Ziarko, Computer Science Department, University of Regina, Regina, SK, S4S 0A2 Canada; 306-585-5213; fax, 306-585-4745.

International Carnahan Conference on Security Technology (AES et al.); Oct. 13–15; Hotel Plaza de la Chaudière, Ottawa, Canada; Gerry Levett, G. Levett & Associates, RR 3, Spencerville, ON, KOE 1XO; 613-989-3242; fax, 613-989-2940.

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Workshop on Speech Coding (COM, SP); Oct. 13–15; Gray Rocks Inn, St. Jovite, PQ, Canada; Lynn Marie Holland, McGill University, 3480 University St., Room 633, Montreal, PQ, H3A 2A7, Canada; 514-398-7475; fax, 514-398-4470.

Fourth Workshop on Workstation Operating Systems—WWOS-III (C); Oct. 14–15; Clarion Inn, Napa, CA; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1903; 202-371-1013; fax, 202-728-0884.

Electrical Insulation and Dielectric Phenomena—CEIDP '93 (DEI); Oct. 17–20; Pocono Manor Inn, Pocono Manor, PA; Alan Watson, University of Windsor, c/o Can AM Mailers, 1927 Rosa Parks Blvd., Box 44901, Detroit, MI 48216; 519-253-4232, ext. 2581; fax, 519-973-7062.

Systems, Man and Cybernetics Conference—SMC (SMC); Oct. 17–20; Palais de l'Europe and Westminster Hotel, Le Touquet, France; M.G. Singh, Computation Department, UMIST, Sackville Street, Manchester M60 1QD, England; (44+61) 200 3347; fax, (44+61) 200 3346.

Workshop on Applications of Signal Processing to Audio and Acoustics (SP); Oct. 17–20; Mohonk Mountain House, New Paltz, NY; Harinath Garudadi, INRS Telecom, 16 Place du Commerce, Verdun, PQ, H3E 1H6, Canada; 514-765-7729; fax, 514-761-8510.

International Test Conference—ITC (C, Philadelphia Section); Oct. 17–21; Baltimore Convention Center, Baltimore, MD; Doris Thomas, International Test Conference, 514 E. Pleasant Valley Blvd., Suite 3, Altoona, PA 16602; 814-941-4666; fax, 814-941-4668.

Joint Power Generation Conference—JPGC '93 (PE); Oct. 17–21; Westin Crown Center, Kansas City, MO; J.S. Edmonds, MCM Enterprise Ltd., 2755 Northup Way, Bellevue, WA 98004-1495; 206-827-0460.

International Workshop on Applications of Neural Networks to Telecommunications (COM); Oct. 18–20; Nassau Inn, Princeton, NJ; Betty Greer, Iwannt '93, Bellcore, MRE 2P-295, 445 South St., Morristown, NJ 07960; 201-829-4993.

Oceans '93 (OE, Victoria Chapter); Oct. 18–21; Victoria Conference Centre, Victoria, BC; Mary O'Rourke, University of Victoria, Box 3030, Victoria, BC, V3W 3N6, Canada; 604-721-8470; fax, 604-721-8774.

Advanced Semiconductor Manufacturing Conference and Workshop (ED); Oct. 19–21; Lafayette Hotel, Boston; Margaret Bachmeyer, Semi, 2000 L St., N.W., Suite 200, Washington, DC 20036; 202-457-9584; fax, 202-659-8534.

International Conference on Computers, Communications and Automation (Region 10, Beijing); Oct. 19–21; 21 Century Hotel, Beijing, China; Zong Sha, Room 2307, 13th Floor, 12 Nongzhanguan Nanlu, Beijing 100026, China; (86+1) 500 1144 3207; fax, (86+1) 500 5233 2307.

International Test Conference (C, Philadelphia Section); Oct. 19–21; Baltimore Convention Center, Baltimore, MD; International Test Conference, 514 East Pleasant Valley Blvd., Suite 3, Altoona, PA 16602; 814-941-4666; fax, 814-941-4668.

International Conference on Network Protocol (C): Oct. 19–22; ANA Hotel, San Francisco; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1903; 202-371-1013; 202-728-0884.

Electrical Performance of Electronic Packaging (CHMT, MTT); Oct. 20–22; Hyatt Regency Monterey, Monterey, CA; Paul A. Baltes, Engineering Professional Development, University of Arizona, Box 9, Harvill Building, Room 235, Second and Olive Streets, Tucson, AZ 85721; 602-621-3054 or 5104; fax, 602-621-1443.

Workshop on VLSI Signal Processing (SP et al.); Oct. 20–22; Conference Centre "Koningshoe" Veldhoven, the Netherlands; L. Eggermont, Philips International, B.V./C DC, Groenewoudseweg 1, 5600 MD Eindhoven, The Netherlands; (31+40) 78 49 61.

International Symposium on Technology and Society—Istas '93 (SIT, NCAC); Oct. 22–23; George Washington University, Washington, DC; William J. Kelly, 320 N. Edison St., Arlington, VA 22203; 703-883-5745.

International Integrated Reliability Workshop (ED); Oct. 24–27; Stanford Sierra Hotel, South Lake Tahoe, CA; Harry Schafft, National Institute of Standards and Technology, Building 225, Room B360, Route 270, Quince Orchard Road, Gaithersburg, MD 20899; 301-975-2234.

Second International Workshop on Intelligent Signal Processing and Communication Systems—Ispacs '93 (COM et al.); Oct. 27–29; Aoba Memorial Hall, Tohoku University, Sendai, Japan; Masayuki Kawamata, Department of Electrical Engineering, Tohoku University, Aoba, Aramaki, Aoba-ku, Sendai 980 Japan; (81+22) 263 9411; fax, (81+22) 263 9411.

15th Annual International Conference of the Engineering in Medicine and Biology Society (EMB); Oct. 28–31; Sheraton Harbor Island Hotel, San Diego, CA; Susan Blanchard, IEEE/EMBS, Box 2477, Durham, NC 27715; 919-493-3225.

Ultrasonics Symposium (UFFC); Oct. 31–Nov. 3; Hyatt Regency Hotel, Baltimore, MD; Harry L. Salvo Jr., Westinghouse ESG, 333 Gordon Ave., Severna Park, MD 21146; 410-765-4290; fax, 410-765-7370.

NOVEMBER

International Conference on Silicon Carbide and Related Materials (ED); Nov. 1–3; Omni Shoreham Hotel, Washington, DC; Gary Harris, Materials Science Research Center, Howard University, 2300 6th St., N.W., Washington, DC 20059; 202-806-6618; fax, 202-806-5367.

27th Annual Asilomar Conference on

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Signals, Systems, and Computers (SP, C); Nov. 1–3; Asilomar Hotel and Conference Grounds; Rabinder N. Madan, Office of Naval Research, Code 1114, 800 North Quincy St., Arlington, VA 22217-5000; 703-696-4217; fax, 703-696-2611.

Nuclear Science Symposium—NSS '93 (NPS); Nov. 2–5; Sheraton Palace, San Francisco; Edward J. Lampo, Lawrence Berkeley Laboratory, 1 Cyclotron Rd., 29/100, Berkeley, CA 94720; 510-486-6779.

Fifth NASA Symposium on VLSI Design (Albuquerque Section); Nov. 4–5; University of New Mexico, NASA Space Engineering Research Center; Sterling Whitaker, NASA SERC, 2650 Yale SE, #101, Albuquerque NM 87106; 505-277-9714; fax, 505-277-9719.

Frontiers in Education Conference—FIE '93 (E); Nov. 6–9; Hyatt Regency–Crystal City, Washington, DC; Charles R. Westgate, Electrical and Computer Engineering Department, Johns Hopkins University, Baltimore, MD 21218; 410-516-7014; fax, 410-516-5566.

International Conference on Computer-Aided Design—Iccad (ED); Nov. 7–11; Santa Clara Convention Center, Santa Clara, CA; IEEE Computer Society, 1730 Massachusetts Ave., N.W., Washington, DC 20036-1903; 202-371-0101; fax, 202-728-0884.

International Conference on VLSI and CAD (ED); Nov. 15–17; Hotel Riviera, Yusong, Taejon, Korea; Kwyro Lee, Department of Electrical Engineering, Kaist, 373-1 Kusong, Yusong, Taejon, Korea; (82+42) 869 3433; fax, (82+42) 869 3530.

38th Annual Conference on Magnetism and Magnetic Materials (MAG); Nov. 15–18; Hyatt Regency Hotel, Minneapolis, MN; Janis Bennett, American Institute of Physics, 500 Sunnyside Blvd., Woodbury, NY 11797; 516-576-2403; fax, 516-349-0247; or Diane Suiters, Courtesy Associates, 655 15th St., N.W., Suite 300, Washington, DC 20005; 202-639-5088; fax, 202-347-6109.

LEOS Annual Meeting (LEOS); Nov. 15–19; and **Optcon '93** (LEOS); Nov. 16–18; San Jose Convention Center, San Jose, CA; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855-1331; 908-562-3893; fax, 908-562-1571.

International Photovoltaic Science and Engineering Conference (ED); Nov. 22–26; Nagoya Congress Center, Nagoya, Japan; Masafumi Yamaguchi, NIT Opto-electronics Laboratories, Tokai, Ibaraki 319-11, Japan; fax, (81+29) 287 7880.

Global Telecommunications Conference—Globecom '93 (COM et al.); Nov. 29–Dec. 2; Westin Galleria Hotel, Houston, TX; Robert A. Finley, Southwestern Bell Telephone, 6500 West Loop S., Zone 3.3, Bellaire, TX 77401; 713-567-8127; fax, 713-567-6133.

DECEMBER

International Electron Devices Meeting (ED); Dec. 5–8; Washington Hilton Hotel, Washington, DC; Melissa Widerkehr, IEDM, 1545 18th St., N.W., Suite 610, Washington, DC 20036; 202-986-1137; fax, 202-986-1139.

Semiconductor Interface Specialists Conference (ED); Dec. 9–12; Bonaventure Resort and Spa, Fort Lauderdale, FL; Lalita Manchanda, AT&T Bell Laboratories, Crawfords Corner Road, M/S 4C 406, Holmdel, NJ 07733; 908-949-1679; fax, 908-949-9017.

Graphics

How cheap can it be and still give you 3-D?

The history of technical computing is awash with wave after wave of price/performance improvements, reflecting the surge of technology advances in an intensely competitive field. Remember the PDP-8/s, for example, the first minicomputer priced under US $10 000 when introduced in 1967 by Digital Equipment Corp.?

More recently, as technical computing has swung strongly to high-performance graphics, marketers have found a whole new frontier to clutter with milestones. In April 1989, Sun Microsystems Inc. introduced its GX accelerator board, which, coupled with the company's Sparcstation 1, cost a little under $16 000 and could generate half a million two-dimensional vectors per second. "It brought graphics to the masses," said Niraj Swarup, product line manager for graphics at Sun in Mountain View, CA.

Only two years ago, Silicon Graphics Inc. (SGI) broke another price barrier by offering what it called the first workstation with three-dimensional graphics for under $10 000. Now, SGI, also in Mountain View, CA, is offering much the same capabilities for about half that figure.


Sun Microsystems Inc.

Sun Microsystems Inc. claims its new Sparcstation ZX has the highest graphics performance priced under US $20 000.

It turns out, however, and to no one's surprise, that reality is often messier and more complicated than marketing departments care to admit. Specifically, reasonable people can disagree about exactly what is meant by "full 3-D graphics."

SGI's new entry-level machine, Indy, was introduced last July 12. Its $4995 base price buys a desktop unit based on the 64-bit, 100-MHz Mips R4000PC microprocessor, with 16M bytes of random-access memory but no disk memory, and a 15-inch color monitor. The graphics subsystem is based on a proprietary chip called Raster Engine for Inexpensive Graphics (REX for short).

Indy was clearly designed with multimedia in mind; a digital color video camera and an analog microphone are both standard equipment. The camera can capture still or moving images at about 30 frames a second, which can be manipulated with optional multimedia software. All the electronics needed for full National Television System Committee (NTSC) resolution are included. "If you want to plug your camcorder into it, you can do that, too," said Richard Grote, director of hardware development for SGI's digital sight and sound division.

In its base configuration, Indy has 8-bit color graphics; these bits can be "dithered" to provide virtual 24-bit graphics, eliminating splotchiness but sacrificing image quality. The machine's 2-D graphics specifications are a quite respectable 500 000 vectors per second, or 1.45 million lines per second, with 10 pixels per line.

For 3-D work, SGI said the machine can generate 26 000 triangles per second—not bad for a $5000 unit. But sticklers might dispute the characterization of these 3-D graphics as "full featured, high performance." Such purists would have to shell out $25 500 for SGI's new Indigo^2 XZ, with 24-bit color, a 19-inch monitor, and a 535-megabyte hard disk. The XZ delivers up to 250 000 flat-shaded triangles a second, according to its maker.

"There's a certain threshold of performance" needed if a workstation is going to be used primarily in 3-D mode, according to Sun's Swarup. "About a year ago it was 100 000 triangles a second. Now, I believe, you need 150 000 to 200 000, at least, before you'd use it all the time for fully shaded 3-D graphics."

Swarup was referring indirectly to the new Sparcstation ZX from Sun, which says the ZX generates up to 310 000 triangles per second. In this base configuration, $19 995 buys a microSparc-based system with 32M bytes of RAM, a 1-gigabyte disk, and a 19-inch monitor. In Swarup's opinion, "there isn't much point in doing 3-D with anything less than that."

Recognizing that some might want to try nonetheless, Sun does have a few lower-priced options. In the same price range as SGI's Indy is Sun's Sparcstation LX. For $7995, it comes with a 16-inch color monitor, 16M bytes of RAM, and a 424-megabyte hard disk.

The LX is essentially a ZX minus the latter's *z*-axis accelerator and 24-bit color; thus like Indy, its forte is 2-D graphics. The machine's graphics subsystem is based on a single-chip implementation of Sun's venerable GX accelerator board. According to Sun, the LX can generate 2-D vectors at rates as high as 480 000 per second. Its 3-D performance of 310 000 vectors per second is adequate for wire-frame 3-D graphics, often used in mechanical and architectural computer-aided design. But 3-D performance of roughly 5000 triangles per second in rendering solid graphics means, essentially, that no one buys it for this particular function.

Hewlett-Packard Co.'s machine in this category, the model 715/33, is also aimed mainly at the 2-D graphics market. Its base price of $5695 buys a desktop unit based on the company's 7100 PA RISC chip, at 33-MHz with 16M bytes of RAM, no disk, and a 15-inch color monitor. HP, in Chelmsford, MA, claims performance of 570 000 vectors, 2-D or 3-D, per second.

Like the Indy and Sparcstation LX, it is an 8-bit color machine and can handle 3-D wireframe graphics. With a $2000 hardware option, called Powershade, it can render 3-D solids at about 12 000 triangles per second, sustained. Higher-priced graphics options give the machine true 24-bit color and much higher performance in rendering 3-D solid graphics.

Convinced that the demand for low-cost rendering of 3-D solids is far from sated, HP introduced an intriguing software feature last November. It allows 3-D images and even full-motion sequences rendered on a networked workstation to be compressed, frame by frame, for display on any X-terminal on the network. Although the compressed images may not be quite so stunning as the originals, the option is suitable for casual 3-D viewing, on terminals costing as little as $3000.

"It's a very real trend, and all of us in the industry are being very aggressive about delivering these capabilities at lower and lower prices," said Robert C. Weinberger, an HP spokesman.

COORDINATOR: Glenn Zorpette

JOBS AT RISK

James Yang

The litany of jobs to be cut, announced by leading high-technology companies around the world in the past year and a half, is tolling the knell of an era: IBM Corp., headquartered in the United States, 90 000; General Motors in the United States, 74 000; British Telecom in the United Kingdom, 65 000; Daimler-Benz in Germany, 40 000; and Nippon Telegraph & Telephone in Japan, 33 000.

Those are only some of the biggest cuts made by the giants; a host of medium-sized companies are themselves letting thousands more go. The cuts range from a few percent to a third of a company's workforce. An untold number of those receiving pink slips are engineers in all company areas, from research and development to manufacturing to management.

Trudy E. Bell Senior Editor

One striking aspect of these cuts is that they are truly international: because so many large, high-tech corporations are multinational, layoffs decreed by the headquarters in one nation are felt by citizens of other countries. For example, half of IBM's cuts of 50 000 employees will be made in Europe, Asia, and elsewhere; 80 percent of Ford Europe's will be felt in England and Germany; and GM's will be felt in Canada and the United States. The carnage ignores political boundaries.

Moreover, the effects of these events ricochet back through the economy. For example, the decline in commercial air travel has meant that fewer airlines need new passenger planes. Airframe manufacturers have therefore ordered less aluminum and fewer components. All these idled contractors and subcontractors mean more people out of work—and the unemployed buy fewer airline tickets.

Worse yet, the vicious circle in civilian aerospace coincides with the ending of the Cold War, the cancellation of major defense aerospace programs, and other military cuts. A number of nations deeply involved in defense aerospace—including Britain, France, and the United States—had hoped that civil aviation would help aerospace companies weather the changing times.

Yet, even with U.S. unemployment hovering at just under 8 percent nationwide (and more than 13 percent in certain high-tech regions such as southern California), the U.S. stock market has been climbing steadily over the last year and a half. Since the beginning of this year, newspaper articles have quoted economists and cited studies purporting to show that the recession has ended and recovery has begun—even while the aerospace company Pratt & Whitney, Connecticut's largest private employer, was letting 7600 go in its home state alone.

How can seemingly opposite developments be happening simultaneously: economic recovery at the same time as layoffs of record proportions? In fact, the companies with the largest staff reductions are beginning to show the greatest gains in profitability. Moreover, far from viewing massive dismissals as a sign of a troubled company, some economic analysts see them as admirable cost-reducing preparations for international competition. British Telecom, for one, got a pat on the back from Jack Grubman, an analyst at PaineWebber Inc. in New York City, who told *The New York Times* on March 21: "If and when the U.K. economy begins to recover, the leverage to the earnings of B.T. is tremendous. They will be exiting the recession with 80 000 fewer people than when they entered."

SEA CHANGE. The explanation, gleaned from the reports of an *IEEE Spectrum* staff editor in the United States along with eight international correspondents reporting from Brazil, Britain, Canada, France, Germany, Hong Kong, India, and Japan, seems to be this: the current huge layoffs are not just the belt-tightening response of many companies to cyclical hard times.

On the contrary, the layoffs are the most visible—and painful—symptom of funda-

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mental and permanent structural (noncyclical) changes in the way high-tech companies will conduct business in the 21st century. Thus, many of those former employees—including the engineers—may never get their jobs back even once recovery is fully under way, because those jobs will no longer exist.

Some characteristics of fundamental change are already evident:

• Lifetime employment is fading even in those companies and countries that have traditionally valued long-term employer-employee commitments, most notably Japan.

• Automation has increased productivity so much that fewer workers are needed to keep up production levels in manufacturing. In fact, the modernization of antiquated plants in developing countries—particularly in the former Communist nations of Eastern Europe—and in China is costing many more workers their jobs.

• Automation is also enhancing productivity in nonmanufacturing service jobs, such as the voice recognition and voice synthesis systems replacing many directory-assistance telephone operators.

• Even with a strong trend toward automation, many high-tech companies in the developed world still find it much cheaper overall only to semi-automate many functions. Instead, they move assembly jobs and even higher-level engineering jobs to other regions where the cost of skilled labor is still as low as a tenth of that at home: northern Mexico for the United States, mainland China for Hong Kong, and Eastern Europe and India for Western Europe. Alternatively, U.S. manufacturers are discovering they can hire temporary skilled factory workers at lower cost than permanent staff.

• Small companies (those with fewer than 1000 employees) have shown a surprising resilience amid the global recession despite many business failures. In fact, in the United States tens of thousands of small high-tech firms have gone on growing and hiring even as big companies were laying off. Why? Smaller companies, with their leaner management structures, niche markets, and faster innovation, have been more responsive to market changes and have had lower overhead costs.

• Big companies in the United States, Canada, and Europe, not slow on the uptake, are restructuring themselves to emulate small companies—a radical reversal from the pattern of most of this century. As computer-aided design and manufacturing have become cheaper, larger companies no longer have a clear advantage in economies of scale; flexibility in manufacturing often counts for more.

All these changes are driven by the same overriding desideratum: to offer high-tech products and services that will compete in both quality and price with all the choices in a stiff international market.

This conclusion—that the layoffs of engineers and other employees at high-tech companies is symptomatic of permanent global alterations—contrasts markedly with the conclusion of *Spectrum*'s December 1990 report, "'90s employment: some bad news, but some good." That report was based on the assumption that the layoffs were a cyclical response to short-term hard times. Moreover, it quoted experts who cited indications of a recovery from the U.S. recession by the middle of 1991 (which turned out to be only a momentary bright spot in a "double dip" recession). It also quoted sources who observed that opportunities were golden outside the United States. Although there are still more opportunities per capita in India, Hong Kong, and Singapore than in, say, Britain, even in developing countries the competition is now getting tougher, and rewards are going mostly to the best-trained and variously gifted applicants.

WHAT IT MEANS TO ME. These trends are felt daily by the individual engineer. Those who have lost their jobs or are fresh out of school find themselves competing with other highly talented candidates for fewer open positions. Those who are still employed may feel their jobs are less secure than in previous years, and may be under pressure to become ever more productive and innovative.

Yet even as the older pattern of a long-term career with one company may be fading, the global trends are also creating demand for engineers in nontraditional fields, such as waste management and environmental control. Moreover, the openings are for a new professional breed: the highly educated, versatile, experienced, polyglot, career free-lance engineer.

Yes, free-lance—in the same sense that writers, illustrators, lawyers, accountants, and physicians have been free-lance: self-employed professionals contracting by the job with a number of clients instead of working exclusively for one company. Although consultants have always been part of the engineering profession, indications are they may be becoming a staple of firms for all work instead of a once-a-year exception on a special project.

"We are in a period between two epochs, a time comparable to the industrial revolution," wrote Umberto Colombo in a prophetic essay published in 1988. (Colombo is a former chairman of the European Community's Committee for the Development of Science and Technology.) "During a transition of this magnitude, past equilibria are disrupted and conditions of mismatch occur in labor markets. The demand for new jobs and skills increases, and old activities disappear or lose their importance in the marketplace."

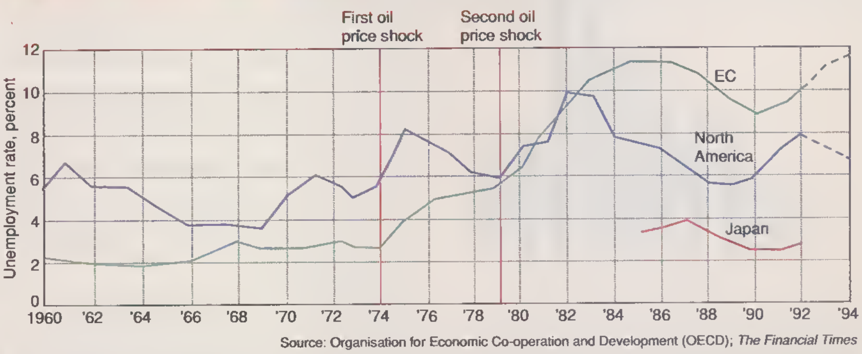
Reporting for this article came from non-U.S. correspondents Axel de Tristan (Brazil), Christopher G. Trump (Canada), Barbara Borst (France), John R. Blau (Germany), Peter Gwynne (Hong Kong), Mohan Raj Sivanand (India), Stuart M. Dambrot (Japan), and Edward Balls, economics leader and feature writer for the Financial Times *(UK).*

The global shakeout: how bad in engineering?

The patterns of engineering unemployment differ around the world. The United States was hit by a simultaneous one-two punch of a recession in the civilian economy (which employs just over half of all engineers) and severe cutbacks in defense spending at the end of the Cold War. Nonetheless, jobs are still being created in smaller companies, and research/consulting firms are among the top recruiters of recent engineering graduates.

Japan continues to resist layoffs as antithetical to its post–World War II custom of lifetime employment. But companies are becoming more aggressive about helping attrition and are offering early retirement incentives, with at least one company, Japan Air Lines, extending its package to employees as young as 35. Many companies are cutting back on their hiring of new

Unemployment in the European Community, North America, and Japan



[1] Unemployment rates for all professions have been steadily increasing in the European Community (EC), while for North America and Japan it has had its ups and downs. By the end of 1994, the Organisation for Economic Co-operation and Development (OECD) predicts that the jobless total will have risen to 23 million in the EC, vs. 8.25 million in the United States and 1.7 million in Japan.

graduates as well. At least one manufacturing plant with 2500 people, the Zama manufacturing plant of Nissan Corp., has been closed—a shock to corporate culture.

Meanwhile, at Mitsubishi Corp. and other companies, there are murmurings at the exorbitant cost of highly paid but unproductive older employees on the "window seat"—a do-little, end-of-career sinecure given as a reward for company loyalty. Although Japan's official unemployment rate is under 3 percent, its underemployment rate is much higher.

Europe's unemployment problems are much worse and not getting any better. According to an economic forecast released in June by the Organization for Economic Co-operation and Development (OECD), by the end of 1994, the jobless total in Europe will have risen to 23 million in the European Community, versus 8.25 million in the United States and 1.7 million in Japan. Moreover, the record for the past two decades shows the underlying number of unemployed has risen, regardless of the ups and downs of the economic cycle [Fig. 1].

According to the OECD in Paris, France, a shift in developed countries away from manufacturing toward service industries, plus their use of new technology to improve the efficiency of what manufacturing they keep, are key reasons for structural (noncyclical) unemployment. Also, new businesses have not been formed in Europe at the rate they have been in the United States, possibly because of high nonwage labor costs and high corporate taxes.

Hong Kong, India, and Southeast Asia, however, still have many opportunities for engineers. Southeast Asia is growing particularly fast, although more than half the businesses in the region are owned by U.S., European, or Japanese firms [see "World electronics production: trends on three continents," p. 22].

U.S. RECORD LOWS. Despite recent upbeat reports of a recovering economy in the United States, unemployment numbers reveal that the last few years have been rough on engineers. At the end of 1991 and the beginning of 1992, figures from the Bureau of Labor Statistics of the U.S. Department of Labor indicate unemployment in all engineering fields peaked at 4.2 percent. That record high exceeded the previous peak of 3.8 percent in the first quarter of 1983, according to Robert A. Rivers, president of Aircom, Union, NH, and the member of the IEEE Manpower Committee who is in charge of employment forecasting [Fig. 3].

Last year alone, the U.S. electronics industry lost some 99 000 jobs, down 4.1 percent from the 1991 figure of 2.39 million, according to the trade group American Electronics Association (AEA), Santa Clara, CA. "The only industry segment that experienced growth in 1992 was prepackaged software, with a modest 2270 new jobs," observed Arnold Silverman, chairman of ICOT Corp., San Jose, CA, and AEA's 1993 chairman. "On the other hand, defense and commercial guidance systems lost 30 000 jobs last year" [Table 1].

According to the AEA figures, December 1992 marked the 30th straight month of no growth in jobs or revenues in the electronics industry; since August 1989, the U.S. electronics industry had contracted by 309 000 jobs, or about 12 percent.

Aerospace jobs have been particularly hard-hit. "Since its peak in 1989, aerospace industry employment has dropped by 29 percent," said Don Fuqua, president of the trade group Aerospace Industries Association (AIA) in Washington, DC. In 1992 the aircraft and parts sector reduced its workforce by 71 000, the civil aircraft production sector by 42 000, and the military aircraft production sector by 29 000.

Although last year was the sixth year of declining employment in the U.S. military aircraft sector, it was the first year of decline in the civil aircraft industry, reversing an eight-year growth cycle and, at least for the short term, dampening hopes that civil aviation might make up for some of the military losses. Further, U.S. air carriers have lost US $10 billion since 1990, the largest and longest period of industry decline since World War II, according to a report by Robert D. Shriner, published in June by the AIA.

A survey done by the AIA shows that employers predict continuing job losses through this year, falling about 10 percent (108 000 jobs) to 942 000 by December. If that happens, then this year would be the first since 1978 that the number of U.S. aerospace jobs falls below 1 million.

According to the IEEE Manpower Committee's Rivers, the impact of the past few years' job losses is more serious than the raw unemployment numbers indicate. For one thing, the Bureau of Labor Statistics' unemployment numbers are very conservative: the bureau does not count as engineers those who are self-employed consultants or who teach at universities. Moreover, the bureau figures may understate actual engineering unemployment: a person is counted as an engineer only if he or she is currently working as an engineer, and is counted as an unemployed engineer only if his or her last job was as an engineer. To the bureau, an engineer taking a nonengineering job is not an engineer; and if that person gets laid off, he or she is not an unemployed engineer.

Rivers also noted that "previous work has indicated that the number of displaced engineers is at least twice as great as the number of unemployed." In other words, if some 4 percent of engineers have no jobs at all, another 8 percent may have been able to find work only in nonengineering fields.

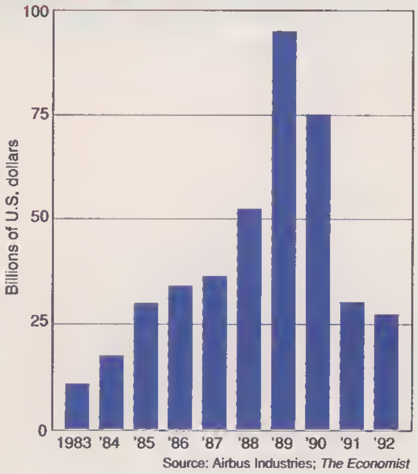
Last year's record high engineering unemployment does not square with the prediction Rivers made in *IEEE Spectrum's* December 1990 report. He said then that engineering employment should begin to recover after early 1991. "Our forecasts were based upon a single variable [the Federal Funds interest rate], controlled by the Federal Reserve Board," Rivers noted.

Historically, that variable, Rivers explained, had correlated with a 71.9 percent accuracy with engineering unemployment, "indicating that approximately 51 percent of engineering unemployment is controlled" by the Federal Reserve Board (FRB) through its practice of making bank loans available to companies to expand their operations. In Rivers's model, up or down moves in the Federal Funds rate occur seven quarters ahead of up or down moves in engineering unemployment. Consequently, the FRB data had for many years been considered a good forecast variable. "At the present time, however, the FRB appears to have lost control of the economy," Rivers said.

GERMAN UNITY'S EFFECT ON EEs. Verein Deutscher Ingenieure (VDI)—the Association of German Engineers—conducts an annual job recruitment study based on 16 major German newspapers and technical magazines. Last year, 44 742 job openings for engineers were advertised, down 12 percent from 50 627 in 1991 [Fig. 4]. The number of job ads for electrical or electronics engineers was down by 3 percent. In contrast, ads for software engineers in Germany were up 11 percent and those for construction engineers, up 73 percent. With a total of 5705 ads, construction engineers accounted for 13 percent of all job openings for engineers; EEs had 12 percent.

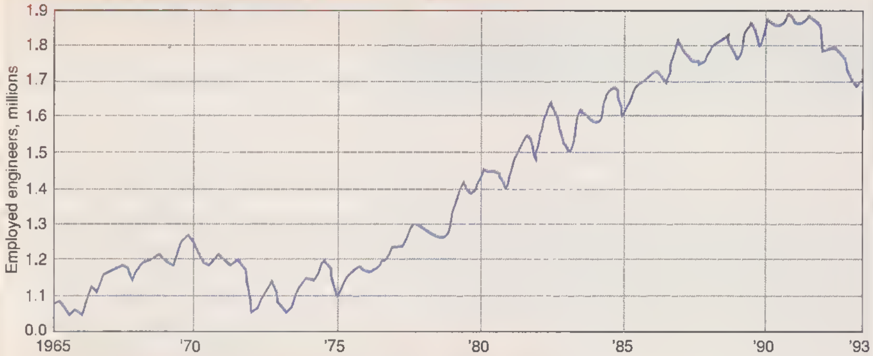
The job market for EEs in the former East Germany is difficult to assess accurately. First, Germany is still in the process of sorting out engineers and technicians in

Decline in commercial jetliner orders



[2] The number of orders for commercial jetliners peaked in 1989, and by last year had fallen below any since 1985. The decline in commercial air travel has been a blow to aerospace companies in developed countries, as they had hoped it might compensate for declines in military aerospace.

U.S. engineering employment, 1965–93



U.S. engineering unemployment, 1965–93

Source: Robert A. Rivers, IEEE Manpower Committee, *Engineering Manpower Newsletter*

[3] Close to 200 000 engineers have been removed from U.S. employment rolls from mid-1991 to mid-1993. This decline exceeds that of the early 1970s, when engineers were hit by aerospace and defense reductions following the Apollo landing on the moon and the winding down of the Vietnam conflict. Engineering unemployment peaked at a record 4.2 percent in the first quarter of 1992, and touched 4 percent earlier this year.

the region by skills and education instead of by job title. Beyond this, the German government has launched several job programs aimed at keeping as many eastern German EEs out of the unemployment statistics as possible, according to Klaus Parmentier, from the Employment and Career Research Institute at Germany's Federal Employment Agency in Nuremberg. Many with jobs, though, work only 2 or 3 hours a day.

The numbers relying on these Government programs are huge. According to a report in the Nov. 5, 1992, issue of London's *Financial Times,* an estimated 1.7 million people in all professions would be registered for unemployment in eastern Germany were it not for the labor programs. About half a million of these people are in full-time training programs, 300 000 are in job creation programs, and 837 000 are on early retirement pensions.

Although the economic slowdown in western Germany has been disappointing to many eastern German engineering graduates who had hoped to find employment there, the engineering job market in the eastern region has all but vanished. Following the collapse of the large state-owned industrial groups, called *Kombinate,* hundreds of thousands of engineers have been thrown out of work. Much of the eastern region's industry was wiped out by the loss of lucrative markets in the former Soviet Union. Its chemicals, auto, steel, and electronics industries essentially collapsed within months of the USSR's dissolution because of their inability to sell to the East and compete in the West.

In addition, jobs in eastern Germany's state-run research institutes are being cut almost daily as federal funds begin to dry up for harmonization programs between eastern and western German industrial research institutes. Many of the R&D centers in the *Kombinate* have vanished along with the *Kombinate.*

Nonetheless, the current tight market for EEs in Germany should be viewed as a transient affair. Germany now is in the middle of a harsh recession affecting most areas of industry. This represents a change from conditions reported in December 1990, when companies with many job openings competed vigorously for engineers. Today, many EEs are vying for a fewer number of openings. Yet most experts feel the market will rebound in three to five years.

Traditional sectors where EEs are still in demand are energy, telecommunications, and construction. All three have much to do with reconstruction in eastern Germany, where new energy plants and power transmission and communications networks have to be rebuilt. On top of this is the building boom in eastern Germany, which has been neglected since World War II and is expected to provide plenty of engineering work well into the next century.

UK'S YEARS-LONG RECESSION. The United Kingdom has suffered high general unemployment for years. After a promising dip in the late 1980s, it is now back up to over 10 percent [Fig. 5]. Meanwhile, for Great Britain's engineering industries, the last three years have been trying. With the country in a recession for two and a half years and despite extensive efforts to cut costs and shed jobs, UK engineering companies still post substantial pre-tax losses.

In recent months, Vickers PLC, London, the UK engineering group, announced a loss of £25.9 million last year, double the loss of the previous year. Rolls-Royce PLC, London, the aero-engine and industrial power group, cut its dividend after incurring a £184 million loss in 1992. And Ford Motor Co., the U.S. car maker in Dearborn, MI, announced that its European car operations fell back into the red late last year.

Not surprisingly, the rise in unemployment caused by bankruptcies—750 000 manufacturing jobs have disappeared since the economy's cyclical peak in early 1989—is being compounded by further layoffs at Britain's main engineering employers. About 5000 jobs will disappear at Rolls-Royce over the next two years, for example, while 10 000 job cuts are planned at Ford Europe by the end of this year, mainly in Britain and Germany.

The Engineering Employers Federation in London calculates that 300 000 engineering jobs have been lost since the end of 1989, bringing the total lost in engineering

1. U.S. electronics industry employment*

	December 1991	December 1992	Change
Computers	463 421	436 635	–5.8%
Semiconductors	255 035	250 949	–1.6%
Other components	351 850	350 488	–0.4%
Prepackaged software	151 409	153 679	+1.5%
Communications equipment	276 600	267 406	–3.3%
Computer programming	193 518	184 097	–4.7%
Instruments	342 089	323 702	–5.4%
Defense, commercial guidance systems	286 474	256 170	–10.6%
Consumer	68 327	67 419	–1.3%
Total employment	2 388 723	2 290 545	–4.1%

Source: American Electronics Association
*These employment estimates are based on data supplied by the U.S. Bureau of Labor Statistics and are subject to later revision.

manufacturing since the early 1970s to a little over 1.5 million. In fact, this field has been the industry leader in jobs lost [Fig. 6].

The employers' federation expects this trend away from manufacturing into service industries to continue throughout this decade. But in a memorandum to the House of Commons Employment Committee, the group noted that it "believes that the decline in UK manufacturing output since the end of the 1970s has been too steep." The memo continued: "Insufficient manufacturing capacity is a significant cause of the present UK recession and now threatens to prevent recovery from recession."

Across the Channel, "unemployment among engineers did not exist until a short time ago," said Gilbert Rutman, president of the national Council of Engineers and Scientists of France, Paris. "Today unemployment has reached management. The layoffs are striking engineers, too."

Those cuts are felt deeply by companies because in France, engineers are regarded as the industry foundation. "It's a great sacrifice for a company to give up its engineers and the investment made in their training," Rutman observed. "They are part of the intellectual capital of the company."

The layoffs of engineers are part of a more general trend, affecting managers as well as line workers, according to Dominique de Calan, deputy secretary general of the Union of Metallurgic and Mining Industries. Despite its name, the union is an employers' group headquartered in Paris that represents more than 500 000 companies in a wide variety of industries. De Calan said the engineering specialties most severely affected are aeronautics, armaments, electronics, computers, and, to a lesser extent, automotive engineering [Table 4].

Usually those laid off have been given early retirement, starting at age 57. "The phenomenon that's new is unemployment among the young, and those 35 and up," added Gilbert Rutman. New graduates used to find jobs very rapidly, courted by many offers. Now, hiring has been so reduced, applicants may wait for months before an offer is made. The number of offers in 1992 was about 30 percent fewer than in 1991; layoffs in 1992 were 2.5 times those in 1988, doubling in the latest 18 months.

According to Rutman, most layoffs have occurred in the heavy industries. EEs have been relatively unscathed, suffering only reduced recruitment. The exception has been the computer industry, which he characterized as "a paradise lost"—deflating now after a period of overinvestment and double-digit expansion.

France's unique difficulty is that in the 1980s, foreseeing an ever-expanding demand for engineers, the French government decided that 80 percent of French students should complete the baccalaureate. Moreover, the number of engineering schools increased from 162 to 203 between the academic years 1981–82 and 1991–92. Together, these factors led to a jump in the number of engineering graduates from 37 762 in 1981–82 to 61 798 in 1991–92. "The number of engineers is growing permanently," said de Calan. "The proportion of engineers [with management qualifications] in France was about 10 percent. It will grow to 12 percent by 1995."

It is worth noting that the French are not quite in synch with other industrialized nations. While there is, for the first time in 50 years, unemployment among engineers, their status remains extremely high. "Here an engineer is Mr. Perfect," declared Rutman. "Polls show that mothers would rather have their daughters marry an en-

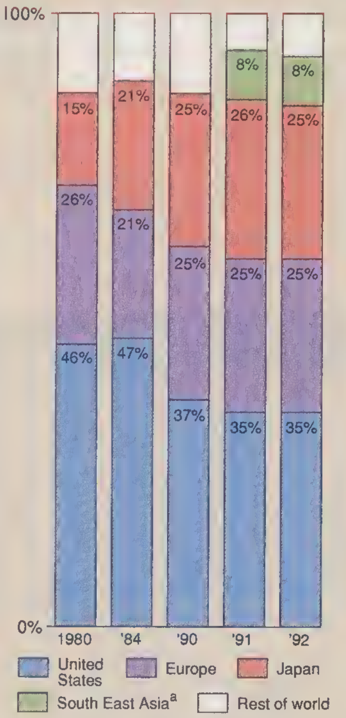
World electronics production: trends on three continents

Because the shape of the world's electronics industry may hint at both short-term and long-term employment opportunities or point out trouble spots in various fields, here is a thumbnail sketch of how the industry is doing globally, according to the Electronics International Corp., Lancaster, PA. The data were published in the company's January 1993 report, *Electronics in the World: A Competitive Overview of the Electronics Industry in the United States, Japan, and Europe*.

In 1992 the world produced US $1013 billion (more than $1 trillion) worth of electronic products, which accounted for about 5 percent of the world's gross domestic product. That is up about 4 percent over 1991.

Computer hardware and software now represent 41 percent of the world's electronics industry (up from 27 percent in 1980). In fact, the communications technology sector—including telecommunications and office equipment as well as computer hardware and software—now represents more than half of the industry. "If income related to fast-growing communications traffic is taken into consideration (voice communications, data transmission, images), communications technologies now represent more than two-thirds of the electronics industry's $1400 billion for products and services," the report stated in bold-face capital letters.

Changing shares in world electronics production



Source: *Electronics in the World: A Competitive Overview of the Electronics Industry in the United States, Japan, and Europe*, Electronics International Corp., January 1993
[a]South East Asia is included in the rest of the world through 1990.

In foreign trade, for the first time Southeast Asia (including Hong Kong, Indonesia, Malaysia, the Philippines, Singapore, South Korea, Taiwan, and Thailand) partially overtook Japan, the report noted. For Southeast Asia, two fields appear particularly favorable: data processing ("a field in which these countries are becoming the largest exporters in the world") and consumer electronics. "Their growth strategy is comparable to that adopted by Japan during the '60s and '70s," the report added.

There is one great difference, however. Japan's growth (as in Europe and the United States) was due almost solely to domestic companies, responsible for the principal share of local production. "The proportion of Southeast Asian production controlled by foreign groups is estimated at almost 50%...in fact, Asian countries outside Japan control less than 5% of world production," the report noted. In comparison, only 6 percent of production in Japan is controlled by foreign groups, 9 percent in the United States, and 27 percent in Europe.

Europe has major problems, the report warned. Its foreign trade has declined steadily, leading to a deficit of about $46 billion in 1991, mostly in the same two industrial sectors in which Southeast Asia excels: data processing (a deficit of $21 billion) and consumer electronics (a deficit of $15 billion). To be sure, Europe has done well in telecommunications, but its market position has shrunk in active components, passive components, and data processing. "This deterioration is so extreme that it raises the question whether the point of no return has not already been reached in some fields," the report stated in bold type. "Europe has not yet become aware of the threats to its electronics industry, and faced with legitimate but contradictory national policies, it has not been able to reach decisions."

In Japan, growth slowed for the first time, falling off by 5 percent in 1992 over 1991; its foreign trade—particularly in consumer electronics—was hampered by the increasing value of the yen, and by the resulting exodus of companies to Southeast Asia, the report said.

The United States now dominates only the fields of computer services, professional electronic equipment, and measuring equipment. But in 1992, it experienced the tentative beginnings of a recovery from its recession, with an overall growth rate of about 5 percent (equipment 4 percent, services 7 percent). The report concluded: "The American recovery should progressively spread to Europe and Japan." —*T.E.B.*

2. Past U.S. employment forecasts, with moderate economic growth

Year of forecast	Baseline: Year	Baseline: Employment	Forecast: Year	Forecast: Employment	Annual growth assumed
Engineers					
1987	1986	1 331 747	2000	1 761 842	2.02%
1989	1988	1 378 860	2000	1 723 869	1.88%
1991	1990	1 483 014	2005	1 876 266	1.58%
All civilians					
1987	1986	101 868 295	2000	122 088 911	1.30%
1989	1988	107 776 700	2000	124 896 630	1.24%
1991	1990	112 053 400	2005	135 280 100	1.26%

Source: U.S. Bureau of Labor Statistics; Richard Ellis, AAES Manpower Studies Department

3. Projected U.S. defense spending and employment

	Total defense outlays, $ billions[a]	Thousands employed: Active duty	DOD civilians	Defense industry	Total
1991 DOD estimate	287.5	2049	1044	2900	5993
1995 DOD estimate	235.7	1653	940	2280–2370	4873–4963
Loss from 1991	51.8	396	104	530–620	1030–1120
Percent loss	18%	19%	10%	18–21%	17–19%
1995 faster reduction	218.0	1653	940	1980–2080	4573–4673
Loss from 1991	69.5	396	104	820–920	1320–1420
Percent loss	24%	19%	10%	28–32%	22–24%
2001 faster reduction	168.6	1340	697	1500–1620	3537–3657
Loss from 1991	118.9	709	347	1280–1400	2336–2456
Percent loss	41%	35%	33%	44–48%	39–41%

Source: Office of Technology Assessment, U.S. Congress, *After the Cold War: Living with Lower Defense Spending*, 1992
[a] Constant 1991 dollars. Includes Department of Defense (DOD) civilian and military personnel stationed overseas.

gineer than a doctor." Because of their status, engineers are also often able to find work in aspects of industry that do not involve engineering per se, such as finance and insurance.

In addition, the French government is still convinced that the country is short of engineers rather than oversupplied, so that to date no call has been made to check the rapid growth in the number of engineering graduates and engineering schools. Instead, the Government has pushed to fill the gap between skilled workers and highly educated theoretical engineers by developing more production engineers with a bit of higher education.

CANADIANS WORK HARDER. "More professional engineers were out of work last year than any time in the past 10 years," reported Stephen Jack, director of programs and events of the Association of Professional Engineers of Ontario, Toronto. (Professional engineer is Canadian nomenclature for a certified or accredited engineer.) As of December 1992, 2.5 percent of Ontario's engineers were unemployed; the previous high was 1.8 percent, at the depth of the 1982–83 recession. (More than half of Canada's engineers work in the province of Ontario.)

A bellwether of the country's economic climate has been the engineering cooperative education program at the University of Waterloo in Waterloo, ON. Waterloo's president, Douglas Wright, said the co-op program, in which students work in companies as part of their education, is the largest of any sponsored by a North American university.

"Since 1957, Waterloo has placed 99 percent of its students" as co-ops with companies, Wright observed, except for 1982–83 and the present, when 10 percent (about 400 students) are still without placements. Although mathematics and science students have fared well, those in freshman engineering have not. "In hard times, companies taking engineering students want those who can contribute as opposed to those just beginning," Wright said.

Waterloo's recent graduates have suffered the same fate. "Five years ago, 98 percent of our graduates were placed within three months of graduation," said John Cullen, Waterloo's marketing coordinator for graduates and alumni. "Now, it's 90 percent, and they have to work hard at it."

Waterloo is not alone in this experience. At the Ecole Polytechnique in Montreal, Canada's largest engineering school, only 54 percent of the graduates responding to a survey mailed by the alumni office have found jobs since June 1992, said André Bazergui, director of the Ecole Polytechnique. "It is demoralizing for our young graduates to hear there is going to be a shortage of engineers while no jobs are presently available," he said. "We must tell them instead that an engineering education is the best way for them to open doors...and not only to engineering positions...[and that] in spite of the recession, engineers are relatively better off."

END OF LIFETIME EMPLOYMENT? The last few years have marked an officially unacknowledged recession in Japan [Fig. 7]. Engineering jobs there are getting distinctly harder to come by. Japan's key high-tech companies have generally not yet resorted to layoffs, but they have reduced hiring. (Unless otherwise noted, all are based in Tokyo.) Nippon Telegraph & Telephone Corp. (NTT) has announced the largest intended shrinkage—33 000 jobs over the next five years—mostly by no longer replacing employees who leave and scaling down the number of new employees hired. Toshiba Corp. plans to employ 950 engineers from new graduates for fiscal 1993, 100 fewer than last year. Following suit, one of its engineering subsidiaries reduced its recruitment of newly graduated engineers from 1400 in 1991 to 700 in 1992.

Similarly, NEC Corp. plans to hire about 10 percent fewer engineers this year because of the recession, said Makoto Maruyama, NEC's general manager of the public relations division. "However, we will not change the policy of adopting a certain amount of newly graduating engineers every year during this decade, because we are convinced that the growth rate of the electronics market will pick up." Fujitsu Ltd. noted that its hiring of college graduates this year is 10 percent lower than last—50 percent lower if technical and commercial high school graduates are included.

"Lifetime employment is not a law, but a custom, and is gradually fading," said NEC's Maruyama. "But, I don't think that the custom will change during this decade, because there are still significant advantages for employers and employees."

Although some Japanese companies such as Pioneer Electronics Corp. and TDK Corp. are trying to reduce the number of manager-class employees, "this movement has caused great controversy in Japan and has damaged the morale of employees in these companies," said Toshiba's representative. "It seems very difficult to change lifetime employment in Japan, and Toshiba will keep this policy."

Fujitsu's representative noted that although the company had closed a 300-employee assembly plant in the United States, "we have not announced any layoffs or factory shutdowns in Japan." When asked about lifetime employment: "What policy? No promises were made, and none were broken," he said.

As the nation with the largest economy in South America, Brazil showed promise a decade ago of rapid development in bringing itself into the modern technical age. But political turmoil in the 1980s, along with high international interest rates, dried up sources of international financing that would have fueled the country's expansion of its infrastructure—including communications, transportation, construction, and information technology. Because of the prolonged recession and the related lack of investment in modernization and plant expansion and production, many engineering positions that should have materialized have not done so.

As a result, the number of qualified applicants exceeds the number of available openings, and salaries have fallen. Today's engineers are poorly paid, even by Brazilian standards, especially given the intensive five-year study that a basic undergraduate engineering curriculum entails. For instance, a senior-level electrical engineer with 15 years of experience employed at Nuclen, the federal nuclear engineering facility in the state of Rio de Janeiro, said that his gross monthly salary amounted to the equivalent of $1500.

Living costs are generally considerably lower in Brazil than in the more developed countries. Nevertheless, $1200–$1500 gross a month is way below scale by international standards for top engineers from some of the finest engineering schools in the country, such as the Escola Politecnica da Universidade Federal de São Paulo (UFSP) or the Escola de Engenharia da Universidade do Rio de Janeiro (UFRJ), or for students with masters or doctoral degrees from the Institute of Coordinated Post-Graduate Programs from the UFRJ. Moreover, $1200–$1500 a month does not

Small is beautiful

The December 1990 *IEEE Spectrum* report, "'90s employment: some bad news, but some good," noted that small high-tech companies were still growing, some very rapidly, despite the overall grim picture in U.S. engineering employment among hardware makers and in the Northeast.

In October 1990, the ongoing survey by Corporate Technology Information Services Inc. (CorpTech), in Woburn, MA, had shown more hopeful signs: in the preceding 12 months some 22 000 high-tech companies with fewer than 1000 employees had reported an average of 5.3 percent expansion in their employment. One in six grew at more than 25 percent. At that time, so many of them were sprouting jobs at such a pace that they were partially mitigating the effects of the massive cuts at the big corporations.

CorpTech now has a database of 24 585 U.S. technology manufacturers with fewer than 1000 employees. Its survey reveals that smaller companies generally weathered the recession better than larger ones, and are leading in the recovery. Now they are growing again, even as big companies are still announcing massive layoffs.

In June, CorpTech reported that employment at the smaller high-tech companies had expanded at an average of 1.2 percent since June 1992. That translates into 16 677 new jobs, generating sales opportunities for their suppliers. More than one firm in seven has grown by more than 25 percent in the last year. Regionally, the fastest growth (4 percent or more) was in the southeastern states, northern New England, and the northwestern and southwestern states; the loss leader by far was southern California, where small and midsized companies shrank by an average of 7.3 percent.

The trend favoring small and midsized companies is not unique to the United States. In Canada, "smaller niche companies are faring better" than bigger companies, said Fiorenza Albert-Howard, public affairs coordinator for the IEEE Canada Region in Victoria, BC.

In Germany, according to the annual job recruitment study conducted by Verein Deutscher Ingenieure, the Association of German Engineers, of 16 major German publications, 44 742 job openings for engineers were advertised in 1992, down 12 percent from 50 627 advertised in 1991. Significantly, most of those ads were from smaller companies. The steepest drop in recruitment ads was noted in large corporations, which published only some 1940 job ads in 1992, scarcely one-fifth the number (9280) of ads they placed in 1991.

Even more significant, for the first time this century, big companies—including IBM Corp. and General Electric Co.—are restructuring themselves into independent business units to look and act like a federation of nearly autonomous companies, complete with individual balance sheets. Among the reasons big corporations often cite for massive layoffs is the desire to "streamline" and to "downsize" to become more flexible and responsive to markets.

Moreover, with the trend toward more customized products and with cost-effective fabrication facilities now available under contract for smaller production runs, smaller manufacturing companies can compete with larger companies, now stripped of the advantage of enormous economies of scale.

—*T.E.B.*

Growth of U.S. high-tech employers of fewer than 1000*

	No. of firms	Number of jobs		Change	
		June 1992	June 1993	No.	Percent
Totals					
Growing annually at over 25%	510	24 450	36 268	11 818	48.3%
Growing annually at under 25%	355	41 397	46 256	4 859	11.7%
Stable	1976	147 624	147 624	0	0%
Shrinking	473	48 771	38 388	–10 383	–21.3%
Failures	63	3 153	0	–3 153	–100.0%
June '93 survey totals	3377	265 395	268 536	3 141	1.2%
June '92 survey totals	3037	335 131	334 929	–202	–0.1%
By industry					
Biotechnology	129	9 938	10 696	758	7.6%
Medical	195	19 572	21 038	1 466	7.5%
Computer software	988	40 700	43 600	2 900	7.1%
Pharmaceuticals	63	8 294	8 722	428	5.2%
Chemicals	123	12 891	13 290	399	3.1%
Advanced materials	218	26 791	27 017	226	0.8%
Environmental	256	26 684	26 874	190	0.7%
Test measurement	396	37 390	37 585	195	0.5%
Holding companies	213	38 143	38 218	75	0.2%
Manufacturing	431	41 618	41 564	–54	–0.1%
Telecommunications	271	28 562	28 469	–93	–0.3%
Computer hardware	566	41 477	41 075	–402	–1.0%
Energy–related	153	16 968	16 685	–283	–1.7%
Transportation	103	16 409	16 014	–395	–2.4%
Factory automation	369	36 544	35 466	–1 078	–2.9%
Subassemblies, components	630	73 986	71 563	–2 423	–3.3%
Lasers optics	186	14 708	14 054	–654	–4.4%
Defense-related	60	9 182	8 770	–412	–4.5%

Source: CorpTech, Woburn, MA
* Many companies are in more than one industry.

go very far even in Brazil with inflation running at 25–30 percent a month.

The Feb. 14, 1993, issue of the Brazilian weekly magazine *Veja* profiled seven Brazilian engineers who graduated in 1980. One of them, 36-year-old Fernando Andrade Affonso of Rio de Janeiro, summed up the attitude of many Brazilian engineering graduates who opted to pursue their chosen profession rather than change fields: "I'm not sorry I became an engineer; I'm just sorry that I became one in Brazil." After having gone through 11 engineering jobs since he graduated from the Escola de Engenharia of the UFRJ in 1980, Affonso has finally set up his own civil engineering consulting firm; although he pulls in less than $1000 a month he said that at least he no longer runs the risk of being fired.

Others have found far more lucrative employment in nonengineering fields such as financial management and portfolio investment. In fact, in Brazil financial management is sometimes referred to as "financial engineering," especially given the intricacies of trying to hedge investments against inflationary erosion.

JOBS IN ASIA. Hong Kong and India are noticeably different from the West and even from Japan because both have plenty of jobs available for engineers. The overall unemployment rate in Hong Kong runs at between 1.5 percent and 2 percent most of the time. For degreed engineers, the rate is markedly lower than that.

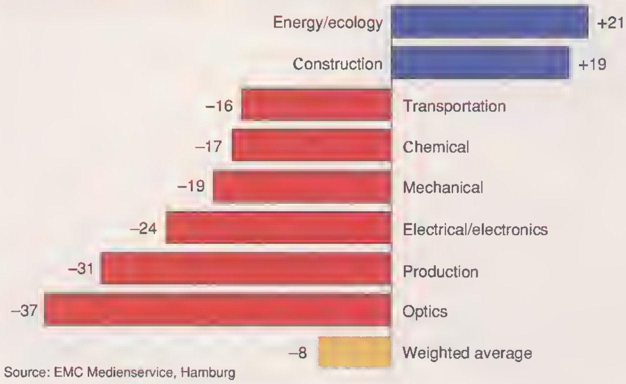
In Hong Kong, because of language barriers, most of the engineers are native to the city. But the number of such individuals working outside Hong Kong—quality control and quality assurance staff can make up to 10–15 percent of workers in some of China's Shenzhen assembly operations—means plenty of vacancies for EEs from the West in Hong Kong itself.

Other factors are attracting contractors and engineers. For example, the territory is building a new airport, which is scheduled to open in 1997, just as Britain hands Hong Kong over to China. True, China has forced delays in the airport schedule, the result of political problems over the degree of democracy to be permitted in Hong Kong before and after 1997; but all sides agree that the airport is necessary and that it will be built, requiring many engineers.

In recent years, the number of faculty members in science and engineering has soared in Hong Kong, as the territory has greatly expanded its tertiary education sector. An important aspect of that expansion has been the new Hong Kong University of Science and Technology, opened in 1991. Departments of computer science, electrical and electronic engineering, mathematics, mechanical engineering, and physics have all had to staff up quickly.

INDIA RAMPING UP. Over the past two years, the Indian government has accelerated many of the economic and trade liberalization measures initiated in the Rajiv Gandhi era. Although India has been called the world's most populous democracy, it had until recently a rigid state-controlled economy. Government monopolized such key areas as power and telecommunications, customs duties were steep, and foreign companies were generally allowed to set up businesses only on a very selective basis.

German engineering recruitment ads, percent change from 1991 to 1992



[4] The number of German career placement ads for engineers with managerial qualifications dropped by an average of 8 percent in 1992 over the number placed in 1991, according to the annual job recruitment study of 16 German newspapers and magazines by Verein Deutscher Ingenieure (VDI), the Association of German Engineers.

Within the last two years, all that has changed. Taxes and customs duties on electronics imports have been further lowered. The Indian rupee (worth roughly 32 to a U.S. dollar) was made a free-floating currency in February this year.

The trend now is toward the creation of a true market economy with a minimum of interference from the bureaucracy. The hastening of these measures was in part inspired by the collapse of the USSR and the changes in Eastern Europe.

The new rules permit businesses almost total freedom in setting up manufacturing units. Anybody may import foreign technology or set up a joint venture. Since 1992, foreigners have been allowed to hold up to 51 percent (in special cases, more) of the shares in a business and have full operational control.

In reaction, the number of new businesses is growing and so is research and development spending [Fig. 8]. Several local electronics firms have started partnerships with big names abroad. Many Indian company names have suddenly added foreign suffixes: HCL–Hewlett-Packard, Mahindra–British Telecom, Modi–Olivetti, and Aircommand–Mitsubishi. Even IBM Corp., which quit India in 1978 because of government control exerted against foreign companies, went back recently.

"The full impact of all this will be visible after another three to five years," predicts Govind M. Phadke, secretary general of the Indian Electrical and Electronics Manufacturers Association (Ieema). "And the impact will depend on the development of infrastructural facilities, especially power, transportation, and communication."

As a rule, most state-owned industries in India are overstaffed—even with engineers. The policy was to provide as much employment as possible, even if an industry suffered losses. But with the new thinking—that market forces must prevail and that even a state-owned industry must be made profitable—and with the partial privatization of many large state-owned corporations, the number of employees is gradually coming down.

But even this is not being done by firing people, explained Srinivasan Ramani, director of the state-owned National Center for Software Technology (NCST), Bombay. "Very few new engineering jobs are available right now in the government and public sector," Ramani said. "Nobody's being laid off. It's just that people who retire are not being replaced for a while."

Much of rural India still lives without electricity, and supplies to urban centers can be erratic. Ieema's Phadke points out that, like other government enterprises, the power sector—almost entirely a government monopoly until now—is overstaffed today [with an estimated 300 000 engineers]. "Even so, because private companies are now allowed to participate, power generation in the 1990s is likely to grow very rapidly, and the power sector would need four to five times the number of engineers it has today," he said.

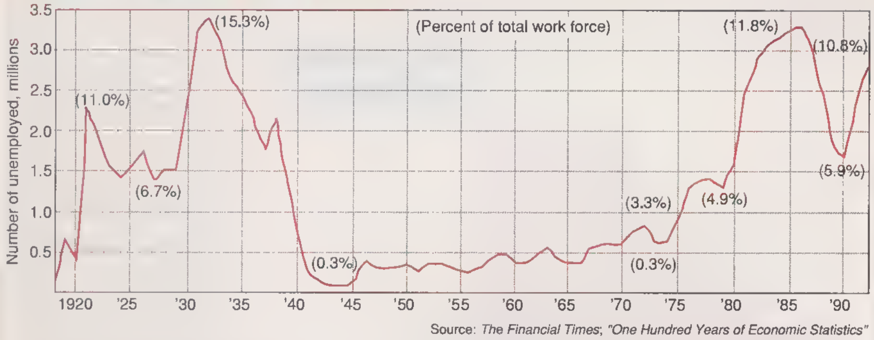
The government's setting up of a new department of telecommunications in 1985 has continued to have positive consequences for EE employment. Until February, the area was also a government monopoly, but it has also been opened to private enterprise.

"Clearly, India is on the threshold of a telecom boom," said telecom engineer Quraish Bakir, general manager of the electronics equipment and devices division for Hinditron Services Private Ltd., a leading computer and telecom firm. He is also secretary of the IEEE's Bombay Section.

Already, Indian engineers are busy laying the groundwork for linking the biggest cities with optical-fiber cables and for rapidly digitizing India's telephone exchanges. Facilities like electronic mail, videoconferencing, and radio paging are beginning to become popular.

Most important, the Government has finally recognized the importance of pro-

UK unemployment since 1920



[5] Unemployment in all professions in the United Kingdom has risen steadily since World War II. Its high of more than 11 percent in the mid-1980s was greater than any time since the Great Depression of the 1930s, and after a short dip is headed upward again.

viding rural India with telephones. Last year 21 800 more villages got telephone facilities; only 1700 did in 1991.

2. Automation and permanent job shifts

One powerful force behind the reduction of employment in all professions is technology: the automation and information technologies and their enhancement of efficiency. Any layoffs due to increased efficiency are likely to be permanent: some jobs simply no longer need people to do them.

Since the U.S. recession bottomed out in 1991, productivity gains have outpaced overall economic growth—the first recovery since World War II in which productivity raced ahead of growth. In 1992, according to the U.S. Department of Commerce, productivity rose nearly 3 percent, its best showing in 20 years.

That rise is why, in part, corporate profits have surged, in spite of a sluggish recovery. Lower interest rates have contributed, but greater output per worker is opening up profit margins. Ironically, these gains have also been one reason unemployment has remained high. Companies can take on more work even while downsizing.

But automation in the sense of factory robots is only part of the story. Information technology is another key determinant. A survey of 400 large companies from 1987 to 1991 shows that the annual return on their investment in information systems has averaged 54 percent for manufacturers and 68 percent for all businesses. The study was done by Erik Brynjolfsson and Lorin Hitt of the Massachusetts Institute of Technology's Sloan School of Management, Cambridge.

Between the two, automation and information technology have allowed companies to overhaul or "reengineer" the way work gets done. In the traditional corporate structure, middle managers relayed information from the factory floor or other divisions to the executive suite, and sped directives from the top to the field. Now, databases and telecommunications networks distribute that information faster.

Evidence of permanent reengineering due to productivity increases and information technology can be seen in the pattern of layoffs: over the past decade, job losses have hit skilled manual workers the hardest. But recently layoffs have also hit white-collar middle managers because information technology has replaced them.

That is good news for companies, which can reduce overhead by eliminating layers in the corporate hierarchy; but it is bad news for the laid-off employees, whose jobs are unlikely to be re-created in a recovery.

Fortunately, engineers—even though they may have managerial rank—have been somewhat more immune to the cuts than manual workers or middle managers. The reason? Not only are they crucial for designing new products, but also "as production processes become more complex, the need for highly skilled technical people continues to grow," said Robert Wilson, of the Institute for Employment Research at the University of Warwick in Coventry, England.

That pattern is evident in the UK. Although the employment of skilled manual workers in the engineering industry fell by 20 000 a year between 1981 and 1991, the employment of science and engineering professionals grew by 17 000 a year over the same time. Those trends are expected to continue throughout the 1990s.

The Institute for Employment Research expects UK manufacturing industries to grow marginally faster than the rest of the economy by the second half of the decade. But layoffs are expected to yield productivity growth of 4.1 percent a year, one percentage point faster than output growth.

CANADA'S PREDICTIONS: OOPS! The Canadian Engineering Human Resources Board, in its annual survey published in Ottawa, ON, in October 1992, estimated that between 1992 and 2002 the demand for engineers in Canada would increase by about 31 000 new positions, to 132 000. Over the same period, the number of practicing engineers is estimated to balloon from about 108 000 to 120 000, reflecting greater immigration and enrollment in engineering schools.

The board has been making such 10-year projections for the past three years under the aegis of an Ottawa, ON, think tank named Informetrica Ltd. To obtain the projections, Informetrica plugs nearly 10 000 variables into 2400 equations in an econometric model. In 1990, the first year of the survey, Informetrica left out productivity improvements as one of the variables and projected a shortfall of 60 000 engineers by the turn of the century. But times were booming then, and few questioned the assumptions underlying the projections.

By 1991 the recession had bitten deeply.

4. Decline in engineering job offers in France

Position	Number of job offers in first half of year 1991	1992	Decline
Manufacturing and construction			
Chemistry, pharmaceuticals & agro industries	142	131	8%
Textile, wood specialists	98	79	19%
Management	273	170	38%
Metallurgy, mechanics	290	140	52%
Electrical, electronics	66	30	55%
Total	1665	941	43%
Computers			
Maintenance	393	314	20%
Business technology	4306	2905	33%
Management	141	91	35%
Systems, networks	1970	869	56%
Other	224	90	60%
Total	8911	4786	46%
Scientific and technical research			
Total	2397	1095	54%

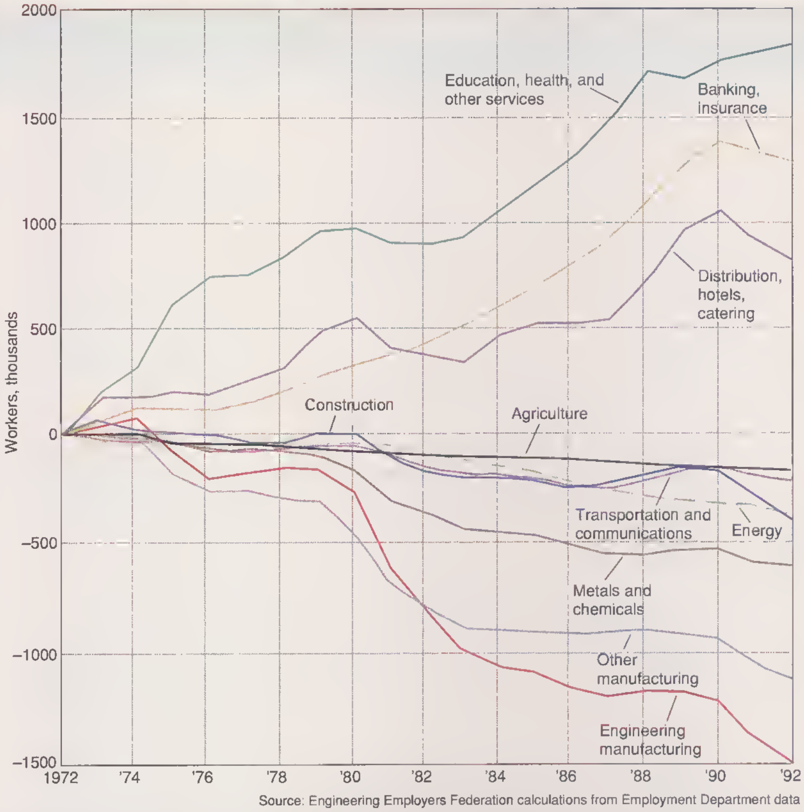
Source: L'Association Pour l'Emploi des Cadres (APEC) (Association for Management Employment)

At the same time, the results of restructuring in many companies showed how changes produced by technology led to fewer employees doing more work. Informetrica added an annual productivity increase of 1.25 percent to its previous projections. *Voilà*, the shortfall in engineers predicted for 2001 dropped to 25 000.

By 1992 the shortfall for 2002 was a mere 20 000, or virtually flat in terms of the capacity of Canada's job market to absorb this number from available engineering talent [Fig. 9]. In addition, Informetrica allowed that attrition of engineers leaving the profession for nonengineering work would be greater than expected, and thus "the supply is greater than previously reported," said the report, titled "Supply/Demand Forecast for Engineers in Canada, 1992–2000." It added, "Net immigration is also expected to be greater than previously projected."

In sum, the eventual shortfall of engineers projected two years ago has all but vanished—due in large part to automation. Even in such a growth area as power generation, where the world by 2020 is projected to need double the megawatt output of the present, "the number of engineers needed will not double," observed Peter J. Schurmann, manager of Siemens AG's power generation department in Mississauga, ON. "Where once we put three project managers on a job, we now have one who can manage easily with the help of a computer. We'll likely be flatline in terms of hiring for the next five years."

Changes in UK employment, 1972–92



[6] Of all categories of UK employment, engineering manufacturing has been the loss leader, contracting by more than 1.5 million jobs over the past two decades. After a sharp decline in the early 1980s, the losses leveled out, but dropped faster again in 1990. Other manufacturing, metals and chemicals, energy, transportation, and communication have also lost jobs.

3. Labor for less

Even though automation correlates closely with vast increases in process efficiencies, all that new equipment is a big investment for a company. Sometimes in the quest to keep products cost-competitive in a ruthless international market, it is simply cheaper not to automate, but to move labor-intensive operations to an area where wages are much lower than at home.

Such high-tech U.S. companies as AT&T, Bendix, Corning, Data General, Digital Equipment, Ford, GTE, Whirlpool, and Zenith have set up manufacturing plants in a 500-km-wide belt south of the border in five northern states of Mexico. The companies have also arranged with Mexican president Carlos Salinas de Gortari to limit raises so as to maintain the low wage level that first drew them there.

In Europe, Germany is one of the most expensive places to do business in the world: labor costs are a third higher than in Japan and the United States. They are also rising faster than elsewhere: industrial wages grew by 6 percent in western Germany in 1992. Moreover, the top corporate tax rate of 50 percent exceeds Japan's 44 percent and Britain's 33 percent.

As a result, 55 percent of all the larger German companies have shifted part of their production abroad or plan to do so, according to a report by the Federal Association of German Industry (BDI, for Bundesverband der Deutschen Industrie). The 55 percent includes giants Daimler-Benz, Robert Bosch, and Siemens. Much of the work has gone to Asia, where labor costs are at least half German levels. The exodus of production jobs has clearly affected electrical engineers, because Daimler-Benz and Siemens are the largest and third-largest high-tech companies in the country, employing more than 33 000 and 39 000 engineers, respectively.

Central and Eastern Europe have also drawn the Swiss-Swedish electrical engineering company Asea Brown Boveri Ltd. (ABB). It now controls about 20 companies in the Czech Republic, Croatia, Estonia, Hungary, Poland, Romania, and Russia employing close to 20 000 people, a figure ABB aims at doubling in five years.

Meanwhile, inexpensive areas of Asia have long attracted Europe, Japan, and the United States [see "World electronics production," p. 22]. But as former low-wage areas, such as Hong Kong, Korea, Singapore, and Taiwan, have themselves become highly industrialized, technically skilled, and affluent, their labor costs have risen so that their own companies are now attracted to areas where people work for less.

Two southern provinces of China are now hot areas: Guangdong, which borders Hong Kong, and Fujian, across the Taiwan Strait from Taiwan. Guangdong province has led the growth, largely because of the influx of Hong Kong's resources.

Guangdong has in abundance what Hong Kong lacks: space and manpower. Hong Kong itself is a tiny territory jam-packed with more than 6 million people. Because of the chronic shortage of space, typical electronics factories stack floor upon grimy floor of assembly operations, with few comforts in the way of air conditioning. Nevertheless, the territory shipped US $2.3 billion worth of subassemblies in 1991.

But over the last few years, the pressures of too little space and too few people have started to squeeze Hong Kong's electronics manufacturers. That realization occurred at just about the same time that the Chinese government was starting a "special economic zone" in Shenzhen, the city that borders on Hong Kong. The zone offers tax breaks and other incentives to employers coming from outside China.

A key incentive is the right to hire and fire. That goes against the grain of decades of Chinese practice, in which workers have been protected by an "iron rice bowl." Government-owned and private companies in China normally guarantee their workers accommodation, food, and a job for life.

Some job losses in the United States

When	Organization	No. of jobs lost	As % of next col.	Total prior employment	How achieved	Reasons given	Where cuts made
11/92–5/93	Amdahl Corp., Sunnyvale, CA	2 000 (footnote a)	23	8 700	Voluntary separation	Recession, erratic demand excess capacity	Most in Sunnyvale, CA
10/92–3/93	Ameritech, Chicago	4 200	6	73 900	Voluntary termination, layoffs	To streamline operations	Service area: IL, IN MI, OH WI
1993	AT&T Co.'s Merrimack Valley Works, North Andover, MA	1 000 (b)	15	6 500	Layoffs	Greater efficiency of network (so less demand for plant's products), more efficient plant	Massachusetts
1992–96	Bellsouth Corp., Atlanta, GA	8 000	8	97 000	Attrition (no layoffs, none projected)	Increasing competition to phone service; streamlining	Service area: AL, FL, GA, KY, LA, MS, NC, SC, TN
1/93–mid-'94	Boeing Co., Seattle, WA	28 000	20	143 000	Half attrition, half layoffs	To trim production of all commercial models except 777; loss of military programs; desire to downsize	Nationwide, concentrated in Kansas and Washington
1993	Commonwealth Edison Co., Chicago	2 125 (c)	12	19 000	Early retirement, layoffs, cancellation of contracts	To reduce cost of operations and maintenance	Northern Illinois; mostly blue- and pink-collar workers
FY 1992– 3 quarters (Q) of FY 1993	Digital Equipment Corp., Maynard, MA	27 700 (d)	22	125 800	Layoffs	Restructuring, downsizing	Worldwide (800 installations in 97 countries)
By end 1993	GE Aircraft Engines, Cincinnati, OH	5 400	16	33 000	Layoffs	Downturn in airline industry; decline in military spending	Primarily Ohio
Q4, 1993–Q1, 1995	General Motors Corp., Detroit, MI	74 000	18 since 1991	304 000 hourly; 91 000 on salary	Closing 23 of 125 plants by 1995; 90% by early retirement and attrition	To reduce overcapacity; restructuring to become more competitive	U.S. and Canada
May 1993	GTE Corp., Stamford, CT	6 400	25	26 000	Voluntary separation	To improve productivity, control costs	CA, FL, TX, and 37 other states
1992–93	IBM Corp.	90 000 (e)	26	344 000	Attrition, early retirement, layoffs	Recession and dwindling market for mainframes; desire to downsize	Worldwide (29 000 in U.S. in '92; half '93 cuts in Europe, Asia)
Q2, 1993–98	Jet Propulsion Laboratory, Pasadena, CA	1 000	13	7 500	Attrition	Reduction in military aerospace work; to emphasize commercial work	Southern California
1993	McDonnell Douglas Corp., Commercial Aircraft Units, St. Louis, MO	8 700	9	92 000	Attrition, layoffs, mainly among blue-collar workers	Declining demand for commercial and military aircraft	Mainly Long Beach, CA; St. Louis, MO; scattered U.S. sites
1993–97	NASA, Washington, DC	5 000 space shuttle jobs	20	25 000 space shuttle jobs	Attrition, civil service transfers	Budget reductions	NASA installations across United States
2/93–1995	Niagara Mohawk Power Corp., Syracuse, NY	1 400	12	12 000	Attrition	To remain competitive; to become more cost-effective	Entire corporation in New York
3–12/93	Northrop Corp., Los Angeles	2 400	7	33 000	1700 layoffs, 700 due to attrition	Dwindling orders for 747 bodies; declining development of B-2	CA, IL, MA
1991–92	Nynex Corp., New York City	3 400	4	84 000	Voluntary separation	To restructure workforce to become more competitive	Service area: U.S. East Coast
End 1992–end 1994	Pratt & Whitney, Hartford, CT	9 000	21	42 700, with Canada	Layoffs	Falling defense orders, poor economy, declining air travel	CT, FL, GA, ME; 2500 with technical degrees
1993	Textron Inc., Lycoming Turbine Engine Division, Providence, RI	1900–2200	4	54 000	Attrition, layoffs	Reduced military spending; worldwide recession in commercial aviation	40% (3500) in Lycoming Division; blue- and white-collar
1/92–3/93	Thiokol Corp., Odgen, UT	2 944	23	12 687	Attrition, layoffs	Cutbacks in NASA budget and Peacekeeper missile program; to become more competitive	AL, FL, LA, MD, NV, TX, UT, and eight countries; tried to keep tech people
Mid-'91–12/94	United Technologies, Hartford, CT	26 000	14	190 000	Attrition, layoffs, plant consolidations	Result of global slump in airline industries and cuts in Pentagon spending	Connecticut mainly, but throughout U.S. and Canada
By 2/93	Westinghouse Electric Corp.'s Western Electronic Systems Unit	4 360 (f)	24–26	17 000 –18 000	Layoffs, comprehensive outplacement	Loss of key military electronics program; soft economy and defense budget decline	Maryland
Q4, 1991 – Q1, 1992	Westinghouse Electric Corp., Pittsburgh	4 000	4	110 000	Attrition, layoffs,	Reduction of market, cutbacks in defense spending, length of U.S. recession	Across U.S., especially Pittsburgh and Baltimore, MD

a In two waves: 900 in November 1992, 1100 in May 1993.
b In 1992, AT&T Co. also announced elimination of 3000–6000 operator jobs nationwide because of more automated technology in network.
c In two waves: 625 in last half of 1992; 1500 in June 1993.
d 12 000 in 1992; 15 700 in 1993. DEC's peak employment was 137 000 in 1989.
e 40 000 in 1992 through attrition and early retirement; 50 000 by end of 1993 mainly through layoffs. IBM's worldwide peak was 407 000 in 1986.
f In four waves: 1200 in February 1991, 1300 in December 1991, 1400 in December 1992, 460 in February 1993.

Shenzhen attracted several multinational companies. Digital Equipment Corp. and Hewlett-Packard Co., for example, produce computer products there at plants they own outright. But of recent years, the chief investors in the special economic zone and nearby parts of Guangdong province have been Hong Kong companies. The main products are motherboards.

For the companies, the zone's appeal is the cheapness of labor. For the assembly workers, it is the high wages—typically US $100 per month, much more than they can earn elsewhere in China. Even Chinese engineers, many of them well trained at universities in Beijing and Shanghai, rarely receive more than US $150 monthly.

"BODYSHOPPING" AND "FLESHWARE". Although India lures Germany with its low wage scale, Indian engineers know that they can make well over 10 times an Indian salary by emigrating to the Persian Gulf or the United States. So, instead of staying at home to work for an Indian salary for a foreign company, some Indian engineers are leaving to command a higher wage abroad.

Many Indian software engineers find jobs abroad on what have disparagingly been called "bodyshopping" and "fleshware" contracts. Earlier, Indian engineers left only for the West, the United States in particular. Now, many go east, to Singapore, Hong Kong, or Australia—in part because their skills are in such demand.

In February, for example, in a two-week employment drive of record proportions, a team of executives from six top Singapore companies—Chem-Solv, General Motors, National Computer Systems, Seagate, Sembawang Shipyard, and Singalab—visited important cities in India seeking applications from graduates in engineering, information technology, telecommunications, design engineering, and instrumentation engineering. Reliable industry sources say they came to recruit about 5000 software engineers, and received more than 25 000 applications.

"When these engineers earn in dollars, they're multiplying their earnings 20 to 30 times over," said S. P. Sukhatme, a senior professor at Bombay's Indian Institute of Technology (IIT), who has just finished writing a book on India's brain drain. Sukhatme feels that the brain drain will endure as long as India stays poor. "In 1955, India and South Korea were equally poor," he explained. "So, many Koreans left for the United States. Today, Korea is rich and you find them returning."

TEMPS IN FACTORIES. One source of cheap labor in the United States is the rapid influx of temporary workers into manufacturing plants. Although "temps" have long been a staple for office work, the downsizing of big high-tech companies has created a growing pool of laid-off skilled technical workers.

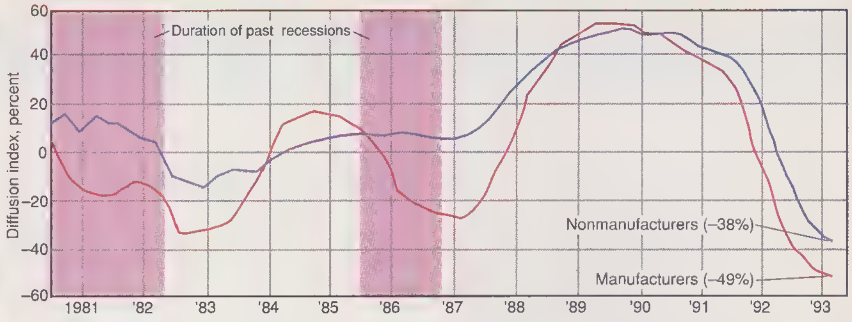
According to the National Association of Temporary Services, Alexandria, VA, a trade group of the companies that supply temporary workers, an average of 348 000 temps a day were provided to manufacturers late in 1992—nearly a fifth of all temporary workers—up from 224 000 a day earlier that year. There may be more, because yet other companies lease out groups of workers to manufacturers, accounting for perhaps another 75 000 persons.

The advantage to a company is clear: skilled technicians can be hired only as needed, incurring no permanent overhead of benefits; moreover, their wages are seldom above entry level, even when the fee to the agency is taken into account. In essence, domestic temps in manufacturing are a source of cheap labor minus the trouble of moving operations outside the country.

The sheer number of temporary factory workers calls into question the exact extent of the stunning productivity increases attributable to automation, acknowledged Edwin Dean, productivity analyst at the U.S. Bureau of Labor Statistics, Washington, DC. According to the U.S. Labor Department, manufacturing has shrunk by 664 000 jobs (to about 17.8 million) since the recession officially ended in 1991. Since production has remained steady as manpower was reduced, that has been taken to mean that each remaining worker has produced more.

The sticking point is that temps are excluded from Labor Department manufacturing numbers. Even on the factory floor, they are counted not as manufacturing workers but as service workers, as their agencies are considered service companies. But if industries have instead hired close to 425 000 manufacturing temps to make up for two-thirds of the loss of full-time workers, then it is possible that productivity gains per worker have been overestimated.

Business ups and downs as seen by Japanese companies



Source: Bank of Japan, *Nikkei Weekly*

[7] Japanese companies no longer fear that the economy will continue to worsen, but are still reluctant to declare a recovery has begun, concludes the Bank of Japan's quarterly tankan survey of business confidence released in June. The tankan survey, which polls 7394 enterprises, calculates a "diffusion index" by subtracting the percentage of companies that say their business conditions are unfavorable from those saying conditions are favorable; it is the most-watched indicator of Japanese business conditions. Last quarter major manufacturers (electrical machinery, steel, and textiles) saw their index worsen.

4. Cold War jobs end

The end of the Cold War destroyed the rationale for a large defense industry. The effects in both the United States and in Europe have coincided with, and amplified, the recession in civilian economies. Certainly, engineers gazing out from the defense industries have felt the squeeze: a paucity of opportunities in domestic commercial enterprises, and a like dearth in other countries should they wish to work abroad.

U.S. DISMISSALS. In 1991, U.S. national defense employed some 6 million people on active duty in the military services, in the civilian ranks of the Department of Defense, and in the private defense industry. "Based on projections of defense spending in the President's 1992 budget, as many as 1.1 million of those positions could disappear by 1995," concluded the U.S. Congress' Office of Technology Assessment in its 1992 report, *After the Cold War: Living with Lower Defense Spending.* "If defense spending is cut deeper and faster (to $169 billion, or 41 percent, by 2001), the defense jobs lost in the four years 1991–95 could add up to as much as 1.4 million" [Table 3].

More than 10 percent of defense workers are engineers, scientists, and technicians. Similar technical personnel form only 4 percent of the nondefense economy. Likewise, precision production workers make up about 7 percent of defense industry workers, but only 3 percent of nondefense workers. "Such highly skilled people are usually in demand," the office observed.

However, 57 percent of defense employment is in manufacturing, compared with 17 percent in the economy at large—and "semiskilled blue-collar workers...have a harder time than other displaced workers in finding new jobs."

If the cuts in defense jobs are made evenly across the board, "as many as 127 000 of the estimated 342 000 defense engineering positions in 1990 may evaporate by 1995," the office warned. That is 37 percent of defense-related engineering jobs.

Consequently, in defense-dependent regions, such as Southern California and mid-Massachusetts, the unemployment rate

has hovered at 1.5–2 times the national average. California's aerospace industry, for example, lost more than 130 000 direct aerospace jobs through February 1993, down nearly 35 percent from a peak of 376 200 jobs in 1988, according to a study on aerospace unemployment by Paul Ong and Janette Lawrence at the University of California at Los Angeles. Also lost were 40 200 jobs in related industries.

Just 16 percent of aerospace workers laid off between April 1991 and June 1992 found new positions quickly; a third were still out of work after seven months, Ong found. Older production workers and engineers fared the worst: of those above 55, more than 40 percent in each category faced more than 27 weeks of unemployment.

The OTA acknowledged that indeed, in the short run, job prospects for engineers and other defense workers have been gloomy because the weak recovery from the 1991 recession has not spawned jobs at the necessary pace. But over the long term, the OTA remained optimistic that the displacement of engineers "is not likely to present major problems." In 1970–73, for example, a high percentage of engineers was unemployed as the civilian aerospace industry declined at the same time as the Vietnam War was winding down. But by the late 1970s and early 1980s, engineers were once again in demand. [For more discussion, see IEEE *Spectrum's* special issue on defense conversion, December 1992.]

UK AEROSPACE HIT. UK companies command 11.7 percent of the world market for aerospace products, compared to a general UK manufacturing industry share of 8.7 percent. Their productivity grew on average 11 percent per year throughout the 1980s, a decade in which annual exports rose from 40 percent of gross revenues in 1980 to 70 percent in 1990. The cost of productivity growth was a drop in employment, from 230 000 workers in 1980 to 186 000 in 1990.

The companies have had a rough recession, with their employment falling by a further 38 000 jobs, according to the Society of British Aerospace Companies, London, to an estimated 148 000 by the end of 1992.

London-based Rolls-Royce PLC accounts for a third of aerospace employment. It blames both defense cutbacks and the falloff of civilian orders for its loss of 12 000 jobs over the past two years and the further 3000 jobs that it will cut in this year followed by 2000 more next year. Sources within Rolls-Royce report that military-related output is now half its level of three to four years ago, and an otherwise excellent book of civilian orders, which in a booming economy might have taken up the slack, has been subverted by repeated delays and deferred orders.

But while the civilian recession is likely to end, a reversal of the downsizing of the defense industry looks less probable. British government figures show that the sum total of jobs related to defense outlays has fallen steadily over the past decade from 710 000 in 1978–79 to 545 000 in 1990–91. Within aerospace, civilian exports have risen as a percentage of total aerospace exports from 40 percent in 1985 to 55 percent in 1991. The same shift has occurred in U.S. industry, but at 81 percent, the civilian share is much higher.

GERMAN EEs GO COMMERCIAL. As German defense contractors follow the trend toward conversion, engineering jobs are being slashed. Krauss-Maffei AG in Munich had annual revenues of DM1.8 billion from defense contracts in the 1980s. Today that figure has dropped to DM500 million.

Still, electrical and electronics engineers are better off than mechanical engineers, said Timm Meyer, a spokesperson for the Federal Association of German Industry (Bundesverband der Deutschen Industrie, or BDI). "Spin in" is the new catchword, he said. Engineers in the German defense sector already are being told to think about civilian applications when developing military systems, a practice that will help them later should they decide to leave for the commercial sector.

5. Strategies for survival

According to official projections, opportunities for engineers around the world will pick up in the next couple of years, but at a slower pace than in past decades. Any recovery will start with a whimper, not a bang.

One fallout of fewer jobs is that an engineering degree alone may not suffice to land a recent graduate a job. Résumés will need the lure of some unusual asset: a nonnative language, a desirable specialty, or some unique experience or talent. The specialty or experience may even lie outside engineering, perhaps in environmental studies, medicine, or law. And engineers may have to be more prepared to work as self-starting entrepreneurs or perhaps within an engineering consulting firm that works for many corporate clients.

What are the immediate and longer-term job prospects for engineers around the world? And how are some imaginative individuals preparing for those prospects?

The U.S. Bureau of Labor Statistics, Washington, DC, in its biennial *U.S. Occupational Outlook Handbook*, has revised its 1991 employment forecast for engineers downward from its 1987 estimate, pointed out Richard A. Ellis, director of manpower studies of the Engineering Manpower Commission of the American Association of Engineering Societies (AAES), also in Washington, DC. Although some bureau analysts expect employment growth for engineers will exceed that for the civilian labor force as a whole, the expected annual rate has decreased from 1987's projection of 2.02 percent to 1991's 1.58 percent [Table 2]. The next update of this biennial analysis will be published at the end of 1993.

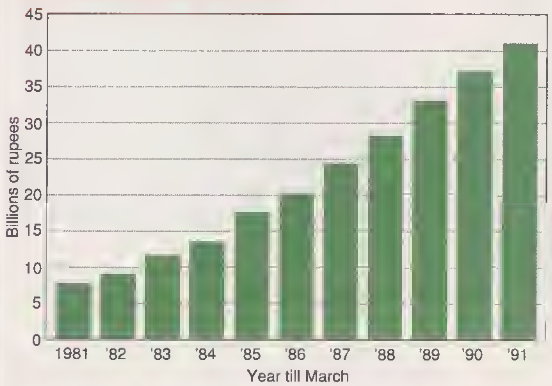
Other analysts believe the growth of jobs in technology companies may lag behind that in other firms. For the 50 industries that employ about 65 percent of U.S. scientists, engineers, and technicians, the expectation is "slower than the total growth in the employment of wage and salary workers in the economy" between 1990 and 2005, noted Douglas J. Braddock, an economist in the bureau's Office of Employment Projections.

Writing in the February 1992 issue of *Monthly Labor Review*, Braddock pointed out that the slower-than-average growth projected for the 50 technical industries was true for all three of the bureau's alternatives anticipating low, moderate, or high growth in the U.S. economy. "In all three alternatives, all but two or three of the industries projected to decline are in manufacturing," Braddock wrote. Manufacturing accounts for 39 of the 50 industries having a high concentration of scientists, engineers, and technicians.

Moreover, "engineers have the widest projected range of employment, from a decline of 2 percent in the low alternative to an increase of 54 percent in the high alternative," Braddock added. "In general, ...supply and demand in the 1990–2005 period are very likely to approximate supply and demand in the 1984–90 period."

Canadian forecasts are somewhat more optimistic, according to the Canadian

R&D spending in India



Source: India's Department of Science and Technology; *Far Eastern Economic Review*

[8] Spending for R&D in India sextupled between 1981 and 1991, an indication of the nation's desire to compete in all forms of high technology. There are at present 32 rupees to a U.S. dollar, so the 1991 Indian investment of 42 billion rupees is the equivalent of US $1.3 billion.

Some job losses in Europe

When	Organization	No. of jobs lost	As % of next col.	Total prior employment	How achieved	Reasons given	Where cuts made
1993	Aérospatiale, Paris	1 150	5	25 360	Early retirement	Slump in aircraft and defense market	Mostly cuts in missiles, space, defense, central management
1993	Audi AG, Ingolstadt, Germany	4 000	11	37 500	Voluntary separation	Recession; to remain competitive internationally; to increase productivity	Factories of Ingolstadt and Neckarsulm
11/90–3/93	British Aerospace, Farnborough, Hants., UK	16 536	14	116 000	Voluntary departures, layoffs, plant closings	To reduce costs in manufacturing, improve efficiency; worldwide recession; downturn in defense and commercial business	13 sites, in England, Scotland, Wales
Over two years	British Gas PLC, London	4 400	6	6B 000	Voluntary separations	Regulatory pressures; to improve efficiency	1200 in London; remainder around UK
Early 1993	British Railways Board, London	7 000+	5	135 000	Voluntary separations	Worldwide recession; loss of passengers	Passenger, freight, ancillary services
Fiscal 1992–93	British Telecommunications, London	39 B00; 30 000 more in 1994–5	19–33	210 500	Voluntary departures	Group restructuring; to improve efficiency	UK, all levels, all disciplines
1993	Daimler-Benz Group, Stuttgart, Germany	15 000 (footnote a)	4	371 000	Attrition, early retirement, release of temporary workers; layoffs (for Deutsche Aerospace defense)	Recession (Mercedes-Benz); reduction in government orders for defense and aerospace products (Deutsche Aerospace)	Mainly in Mercedes-Benz (7000) and Deutsche Aerospace (5600)
8/92–7/93	Porsche AG, Stuttgart, Germany	1 B00	22	B 062	Attrition, layoffs	To increase productivity, streamline management, return to profitability	All departments and divisions
From 10/92	Ford of Europe Inc., Brentwood, Essex, UK	10 000	11	94 000	Voluntary separations	To reduce over-capacity, improve efficiency, become more competitive	80% in UK and Germany
End of 1994	Groupe Bull, Paris	6 500 (b)	1B	35 175	Varies by country	Economic conditions	Worldwide across the board
By B/93	Renault Véhicules Industriels SA, Lyon, France	1 34B	8	17 900		Recession, sales down	France
1993–94	Rolls-Royce PLC, Aerospace Group, London (c)	5000	17	29 500	Voluntary separations, plant closings, "layoffs not ruled out"	Defense cuts, recession in commercial aviation, business consolidations	Primarily UK, cross section of workers
One year	Saab Automobiles AB, Trollhättan, Sweden	195B	21	9 200	Layoffs	To reduce operating costs	Three sites in Sweden
By 10/93	Siemens AG, Munich	16 000	4	413 000 worldwide	Attrition	Worldwide recession; lower demand for computers; international competition	Principally medical computers, semiconductors
1992–93	Snecma, Paris (d)	1 400	10	13 700	Early retirement, voluntary separation	Slump in defense and commercial aviation	1992: mostly production workers; 1993: mostly others
By mid-'93	Tungsram, Budapest, Hungary (e)	940	9	10 200	Attrition, early retirement, layoffs	To increase efficiency	Seven lamp-making and two machinery plants, plus headquarters

a Includes Mercedes-Benz, Deutsche Aerospace, AEG, and Daimler-Benz Inter Services (Debis).
b Worldwide staff already cut by 9000 (19%) during 1/90–12/92. The figure of 6500 includes cuts at Zenith Data Systems, a Bull affiliate headquartered in Illinois. Has shed staff steadily since 1988, when it had a worldwide work force of 45 000.
c The Aerospace Group represents more than half of Rolls-Royce PLC, which employs 52 000. d Société Nationale d'Etude et de Construction de Moteurs d'Aviation. e Is 75 percent owned by General Electric Co.

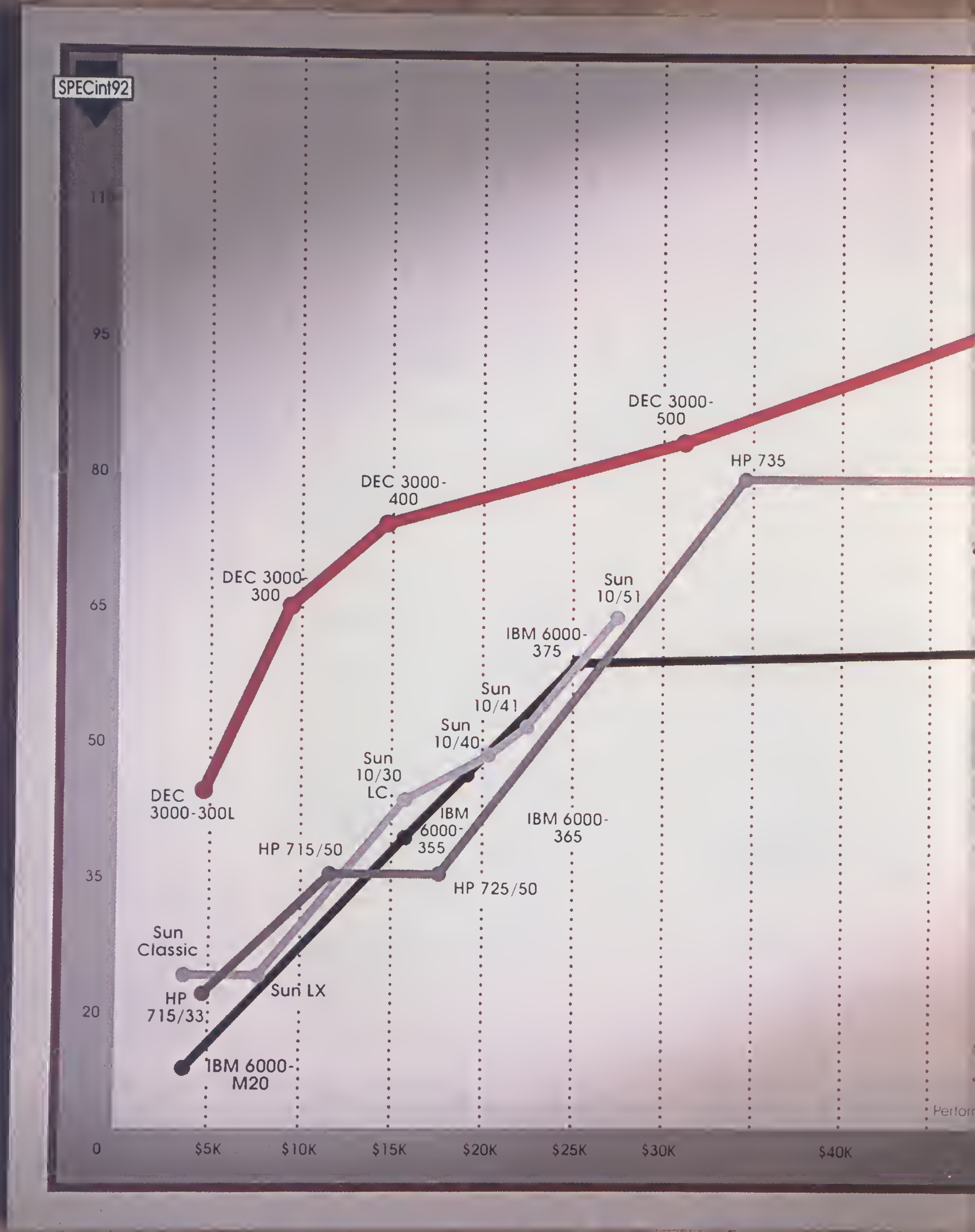
Engineering Human Resources Board's October 1992 report, "Supply/Demand Forecast for Canadian Engineers 1992–2002." While acknowledging that in early 1992 economic slowdown reduced engineering employment significantly, the report noted that "each of the last two decades has experienced a major recession during which the unemployment of engineers rose to relatively high levels."

In the United Kingdom, forecasts for engineers are grimmer than in North America. The Institute for Employment Research at the University of Warwick in Coventry expects total employment to rise by an average 0.5 percent a year between 1991 and 2000. But manufacturing employment is predicted to slip by 1.5 percent a year, a further loss of 600 000 jobs.

The rate of decline in engineering employment—at 1.4 percent a year from 1991 to 2000—is broadly in line with the rest of the manufacturing sector but an improvement over the past decade. UK engineering jobs fell by 748 000 in the 1980s and are expected to shed a further 263 000 in the 1990s, with most of the job loss over by 1995. If the institute is correct, then the share of engineering employment in total UK employment will slip to 7.5 percent by 2000, down from 8.76 percent in 1991. The share will be half of its level in 1954.

MORE THAN AN EE DEGREE. "Restructuring means that there is a lot of variety needed," observed Philip A. Lapp, past president of Canada's Association of Professional Engineers of Ontario and president of Radarsat International, headquartered in Toronto. "Engineers who are multifaceted are going to do well."

As always, engineers with graduate education are much better positioned than



imagine working faster than you ever

Some job losses in Japan

When	Organization	No. of jobs lost	As % of next col.	Total prior employment	How achieved	Reasons given	Where cuts made
By 7/93	Fujitsu Ltd., Tokyo	400–500	0.8–1.0	52 000	Attrition, reduction in recruitment,[a] transfers	Downturn in economy; streamlining operations	20% of 2100 administrative jobs
By 6/93	IBM Japan Ltd., Tokyo	1200	4.8	25 000	Voluntary early retirement	To streamline business worldwide	Across the board
By 1998	Kokusai Denshin Denwa Inc. (KDD), Tokyo	800	13.7	5 800	Fewer new hires, transfers to subsidiaries, no layoffs	Restructuring to increase efficiency and productivity	2600 technical
By 1998	Nippon Telegraph & Telephone Corp. (NTT), Tokyo	33 000	14.1	233 000	Fewer new hires, transfers, no layoffs, closing about 700 of 370 sales offices	Increased pressure from competition; weak economy	Sales, service, maintenance personnel; telephone operators
1993	Sanyo Electric Co., Osaka	3600	11.8	30 600	Attrition, shift of production to Asian plants	To streamline operations; restructuring	N.A.

N.A. = not available. a Now recruits about 300 university graduates a year, down from previous 2000.

those with simply a baccalaureate. In the United States today, the differential in starting salary for someone with an engineering Ph.D. as opposed to simply a bachelor's is US $23 000–$27 000 per year. The career placement offices of the Rensselaer Polytechnic Institute, the University of Michigan, the California Institute of Technology, and the University of California at Berkeley reported that the average starting salary for one of their EE graduates with a bachelor's degree was $34 000–$37 000, while those with a doctoral degree commanded $56 000–$64 000.

A hefty differential also goes to those whose graduate degree is not in engineering. People who add an MBA to a technical bachelor's degree plus a couple of years of experience are landing jobs starting on average at more than $53 000, according to Dawn Oberman, statistical services expert at the College Placement Council Inc., in Bethlehem, PA.

Similarly, in France, young engineering professionals in growing numbers are adding to their versatility by earning an MBA or other nonengineering degree. "There is a fundamental shift in industry, an elevation of competence," noted the Union of Metallurgic and Mining Industries' Dominique de Calan.

Other skills besides graduate degrees are coming to be highly valued in an ever more global marketplace. Western engineers compete fiercely even for the many posts in Hong Kong and China. Those hired are those who know—or are prepared to learn—Cantonese, the Chinese dialect spoken in Hong Kong and the parts of China that surround it. It is even better if one also knows Mandarin, the classic language of China. (Cantonese and Mandarin share written symbols, but when spoken sound about as alike as, say, English and German.) "In previous years, English was sufficient," said Po S. Chung, head of the department of electronic engineering at the City Polytechnic of Hong Kong and chairman of the IEEE Hong Kong section. "Now, Cantonese is essential and Mandarin a great help."

So is knowledge of the local politics and culture. "Increasingly multinationals have to deal with China on many matters," explained Chung. "So there's a great demand for local expertise." Opportunities abound only for those who offer more than the typical engineer's résumé.

FREE-LANCE ENGINEERS. With the trend toward downsizing and restructuring of work, big companies are hesitant to rehire and grow fat again. So when they need more help than a lean in-house staff can give, they are increasingly turning to independent engineering contractors.

As one result, consulting services employers are accounting for an ever greater percentage of job offers to recent graduates than in past years: 9.6 percent of all job offers to technical undergraduates in 1992–93, up from 7.8 percent in the year before, according to the College Placement Council's Oberman.

In fact, engineering research and consulting firms have been the one of the two biggest categories of recruiters (along with electrical and electronic machinery and equipment firms). Consulting firms made 16 and 17 percent of all offers to graduates, respectively, at the University of Illinois in Urbana-Champaign and the University of Michigan in Ann Arbor—percentages that far outstrip that from the category of computer, data processing, or information technology companies.

Many of these consultants are well-known firms of the usual kind, paying engineers a salary plus medical and retirement benefits. But another trend is the increasing number of individual engineers who are setting up their own independent consultancies. This trend is evident in Canada as well as in the United States. "There is a great deal of 'outsourcing,'" noted Fiorenza Albert-Howard, public affairs coordinator for the IEEE Canada Region in Victoria, BC. "Engineers are laid off and then hired back again as consultants. They are no longer part of the company's head count."

A third trend is free-form outsourcing companies. In Toronto, for instance, in July 1992, four veterans of the computer industry founded Virtual Corp., an allusion to the intangibility of its facilities.

Using "groupware" computer networking software by Lotus Development Corp., Alan Hutton, Donald Parker, Douglas Weir, and Edward White constructed a loose, company-like framework for about 150 independent consultants. Working teams form and dissolve according to clients' needs. Engineers scattered hundreds of kilometers apart in offices and homes can work on the same documents and charts at the same time, instead of trading files back and forth. Associates, who remain self-employed, pay a fee to join the network and gain access to its special services; in return, Virtual Corp. provides group discounts on insurance, long-distance telephone service, and access to databases and job banks.

Outside North America, experts in India have predicted that a liberalized economy in that country will in the 1990s turn a great many engineers into self-employed entrepreneurs. For the best EEs, that would be preferable to working abroad.

NEW FIELDS. Opportunities, however, are growing for those with engineering credentials in fields only tangentially related—or even unrelated—to engineering.

In Germany, for example, a new demand for engineers is generated by environmental control. The country is a leader in waste control management and antipollution technology. According to statistics compiled by the German Waste Treatment Association, almost 700 companies employing some 70 000 people are now commercially involved in disposing of German industrial and household waste. Mechanical and electrical engineers are being called upon not only to develop new technologies to manage waste but also to design low-pollutant vehicles and to modify products for recycling, said Hanskarl Willms, a spokesman with the Waste Treatment Association.

In Canada, engineers employed outside engineering earned more on average (C $80 505) than those inside engineering-related fields (C $69 037). Those wholly immersed in engineering earned least, on average C $62 262.

According to the annual survey of the Association of Professional Engineers of Ontario, the most highly paid Canadian engineers in 1992 were in data processing, at

an average salary of C $81 686, up a whopping 12.7 percent over the previous year. By specific job functions, general management pays best, at an average C $86 976 annually, with university teaching next at C $81 212. The lowest-paying jobs are pure engineering: quality assurance, production engineering, and design, respectively, paid C $57 349, C $55 534, and C $52 244.

While these nonengineering opportunities are good news for the imaginative individual intrigued by a career switch, there is a problem for society at large: if the salary differential between the two job categories is too great, a nation can lose its engineers even if they stay within its borders.

According to Carl Méeus, writing in the Oct. 19, 1992, issue of *Le Figaro*, the large French daily newspaper, by the end of the 1980s some 30 percent of fresh engineering graduates fled production for more attractive non-engineering functions, such as finance, marketing, banking, and insurance. And in India, some 60–70 percent of the graduate students in management schools are engineers. Most are the EEs with the best grades.

LONG-TERM QUESTIONS. The general message seems to be that in the latter part of this decade and beyond, engineers the world over must become even more highly educated and broadly experienced than ever before, to stay afloat in a pool of jobs that is growing more slowly than in the past. (The presumption, of course, is that in the 1990s there will be no radical "wild card" development to create a boom in engineering R&D, as the microprocessor did in the late 1970s and beyond.)

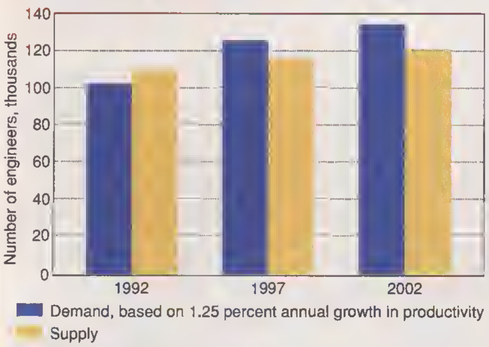
But what the trends toward downsizing and contract work may mean in detail to individual engineers, their companies, and their respective nations is not yet clear. From the corporate perspective, companies outsourcing their R&D functions may well have to revolutionize their structures to guard intellectual property rights—especially trade secrets—against free-lance consultants who work for the competition as well. From the individual perspective, the uncertainty of employment and medical and retirement benefits in engineering may deter people who prefer to work loyally for one company, contributing to its growth and well-being in exchange for security.

"What may be good, or even necessary, for a company in the short run may be devastating in the long," observed Daryl Chubin, of the U.S. Congress' Office of Technology Assessment in Washington, DC. "Highly trained human resources may rebel against forced 'free agency' and change fields altogether. The job market signals to the next generation—prospects are few and uncertain—could be devastating."

Another interpretation is possible. "We are witnessing the sharpened decline of the factory as the primary function and chief labor-absorber in industry," wrote Umberto Colombo in his insightful 1988 essay on the technology revolution and global restructuring. "Now manufacturing becomes ancillary and even a candidate for contracting out," he prophesied, much as agriculture late in the industrial revolution became mechanized and no longer dominated the economy as a main source of jobs.

In a transitional period between two epochs—the industrial epoch of mass production and the mature information age, such as this time may well be—there is "widespread fear of the future," Colombo wrote. That fear derives from "the difficulty of even imagining the range of opportunities that an ongoing revolution brings in terms of new opportunities and related jobs."

Demand and supply of engineers in Canada, 1992-2002



Source: Canadian Engineering Human Resources Board, *Supply/Demand Forecast for Canadian Engineers, 1992–2002*, October 1992

[9] Although there were more engineers in 1992 than there were jobs available for them, by 1997 opportunities are expected to appear, according to a forecast last year by the Canadian Engineering Human Resources Board. The engineering labor force in 2002 is expected to total about 120 000, compared with about 108 000 last year. About a third of those new engineers are expected to be EEs.

TO PROBE FURTHER. Umberto Colombo's prescient essay, "The Technology Revolution and the Restructuring of the Global Economy," was published in *Globalization of Technology: International Perspectives*, edited by Janet H. Muroyama and H. Gayford Steven (National Academy Press, Washington, DC, 1988).

The effects of the global recession on international air travel and how they ripple through to the orders for jet aircraft and the employment in civilian aerospace are detailed in "Airlines: Losing their way," the June 12, 1993, issue of *The Economist*, pp. 3–22.

The effects of the end of the tensions between the United States and the former Soviet Union on U.S. employment in both the Federal government and in defense-related companies are discussed in *After the Cold War: Living With Lower Defense Spending*, from Congress' Office of Technology Assessment, Washington DC, 1992 (Publication OTA-ITE 524.)

Employment trends—especially at smaller companies—are tracked monthly by the corporate directory publisher Corporate Technology Information Services Inc. (CorpTech), 12 Alfred St., Woburn, MA 01801; 617-932-6335.

Robert A. Rivers's projections of engineering unemployment can be found in various issues of *Engineering Manpower Newsletter*, published by Rivers: Box 129, Union, NH 03887.

Douglas J. Braddock analyzed the U.S. Bureau of Labor Statistics' projections for jobs available to scientists, engineers, and technicians in "Scientific and technical employment, 1990–2005," published in *Monthly Labor Review*, February 1992, pp. 28–41.

The Canadian Engineering Human Resources Board's *Supply/Demand Forecast for Canadian Engineers 1992–2002*, published in October 1992, is available from G. Lozano, Canadian Council of Professional Engineers, 401-116 Albert St., Ottawa, ON, K1P 5G3; 613-232-2474.

The French Association for Management Employment (L'Association Pour l'Emploi des Cadres—APEC) publishes an annual report *Emploi Cadres Perspectives* discussing the previous year's recruitment and employment of managers, including engineers. The April 1993 report can be obtained by writing to APEC at 51, Blvd. Brune, 75689 Paris Cedex 14, France.

An article examining the plight of engineers in France is "Ingénieurs: la fin de l'age d'or?" ("Engineers: End of the Golden Age?") by Agnes Baumier, published in the French newsweekly magazine *L'Express*, Feb. 14, 1993.

An article about engineers in Brazil profiled seven who graduated in 1980 and chronicled why they chose to leave engineering for other fields: see "Os filhos da decada perdida," ("The children of the lost decade,") in the major Brazilian newsweekly magazine *Veja*, Feb. 17, 1993, pp. 48–56.

In "Titans in Town," Pranjal Sharma and Saritha Rai describe the multinational joint ventures between major European, Japanese, and U.S. high-tech companies and companies in India, and their effects on native Indian products and markets. The article appeared in *India Today*, Jan. 15, 1993, pp. 94–95.

A succinct summary of the interim report by the Organisation for Economic Co-operation and Development (OECD) on Europe's inexorably growing unemployment is "A tide that's not for turning" by Edward Balls, *Financial Times*, June 9, 1993.

Japan's tradition of "window-sitter" jobs and the toll they take on productivity is examined by Yumiko Ono in "Unneeded Workers in Japan are Bored, and Very Well Paid," *The Wall Street Journal*, April 20, 1993, pp. A1, A10. ◆

Acknowledgments. Thanks are also due to Alan Gardner, Mary Knight, and Joan Agranoff for their extensive fact checking of the tables of European, Japanese, and U.S. job losses.

Putting data on a diet

A variety of techniques for data compression can ease a variety of problems in storing and transmitting large amounts of data

Downsizing may be a buzzword in business, but the opposite is true in the world of digital data. In every application area, the number of bytes that need to be stored and transmitted is growing at an enormous rate, posing problems for those who work with them.

Word-processing programs, which fit comfortably in less than 100 kilobytes back in the PDP-11 era, today can easily occupy 10 megabytes. The entertainment industry is experimenting with video-on-demand services as an alternative to the renting of videotapes—a development that will involve the transmission of tremendous amounts of digital data. Meanwhile, computer networks are becoming more decentralized and in need of high-speed interconnections over long distances.

Because of these trends, disk drives that looked gigantic only two or three years ago have suddenly become inadequate. More important, communications costs are rising. But when companies try to save money by using fairly low-speed wide-area networks (WANs) to interconnect their fairly high-speed local-area networks (LANs), users are frequently frustrated by the queuing delays that result. (A typical WAN operates at 64 kb/s or less—a reduction in bandwidth of over 150:1 compared with a high-speed LAN.)

The solution to all these problems is the same: data compression. Within well-understood theoretical limits, compression trades some computational complexity for reduced bandwidth and storage requirements. It employs sophisticated algorithms to search data for redundancies, which it removes to make the data set smaller. After transmission or storage, the compressed data is restored to its original form by a complementary decompression algorithm.

How do these compression algorithms work? Which are suitable for which applications? And what issues are likely to arise as they are increasingly applied to WANs? Before attempting answers, it is helpful to differentiate between lossy and lossless compression.

TO LOSE OR NOT TO LOSE. Lossless data-compression algorithms preserve all the information in the data so that it can be reconstructed without error. Because they must work perfectly, their compression ratios are only a modest 2:1 to 8:1, depending upon the redundancy of the information source and their own capabilities. Lossless algorithms are mandatory for transmitting or storing such data as computer programs, documents, and numerical information, where a single bad bit could lead to disaster.

Jeffrey Weiss and Doug Schremp Telco Systems

Defining terms

ASCII: American Standard Code for Information Interchange, a code in which each symbol is represented by one byte (8 bits).
Escape sequence: a sequence of bytes that begins with the escape character.
Hash table: a table of pointers, typically to text strings in a buffer.
LAPB: link access procedures (balanced), the error detection and retransmission procedure used in X.25 networks.
TCP/IP: transmission control protocol/internet protocol, the protocol used on the Internet and by most Unix-based computers.
X.25: a packet-switched data-communications protocol in which extensive error correction is applied at every node.

Lossy compression techniques do not offer perfect reproduction, but can compress data into as little as 1 percent of its uncoded length. The information recovered only approximates the source material, but that is enough in many applications—for images and sounds destined for human eyes and ears, for example.

Although the present boom in data communications is highlighting the need for lossless compression techniques, the concept has been around for quite a time. Providers of tape-based computer backup equipment realized early on that recurring media costs could be cut at least in half if they added compression to their offerings. They also recognized the need for speed. The first systems were software-based and stretched out backup times unacceptably; most processors could not process data at the streaming rate of a typical tape drive. The suppliers dodged that obstacle by including compression chips on their controller cards. With that dedicated hardware, backups are performed at full speed.

The challenge remains the same today: find a means for spending as little time as possible on packing as much information as possible into as little space as possible, and with no loss of data. One new spur to the search for better compression algorithms is the trend for some public data carriers to procure at least some of their bandwidth from other carriers. To reduce their costs of transport without compromising the services they provide, they require lossless compression techniques that operate in real time.

LOSSLESS LIMITS. How much compression can they reasonably expect to get? In the late 1940s Claude E. Shannon discovered that the extent to which a message can be compressed and then accurately restored is limited by its entropy. Entropy is a measure of the message's information content: the more probable the message, the lower its entropy. It is expressed in bits as the negative of the base-2 logarithm of the message's probability.

Entropy may be thought of as a measure of surprise. If the contents of a message are unexpected, then its entropy is high. If the contents are as expected, then entropy is low. The more probable a message, the fewer the bits required to encode it.

Consider a fair die with six faces. The probability of any throw is the same, 1/6. The entropy is therefore 2.6 bits—that is, $-\log_2 (1/6)$. In other words, slightly less than 3 bits are required to represent the outcome of any throw of a fair die. Only if the die is loaded can the outcome of a throw be represented with fewer bits.

The good news is that the die *is* loaded when it comes to compressing "typical" data. Hence, a careful examination of the data stream will uncover significant redundancy. Lossless compression strives to get rid of this redundancy without loss of information.

In practice, the entropy of any message depends upon the sophistication of the model used to evaluate it. To repeat, the more accurately a message may be predicted, the fewer the bits required to encode it. For example, when a simple memoryless (Order-0) model is used to represent the alphabet, the letter *u* may have only 1 chance in 100 of occurring in the text under evaluation. It will therefore always require a minimum of 6.6 bits to encode. On the other hand, if the preceding letter is taken into account (an Order-1 model is used), then, when the preceding letter is a *q*, the probability of a *u* (in the English language) will be approximately 95 percent, which can be encoded with only 0.074 bit.

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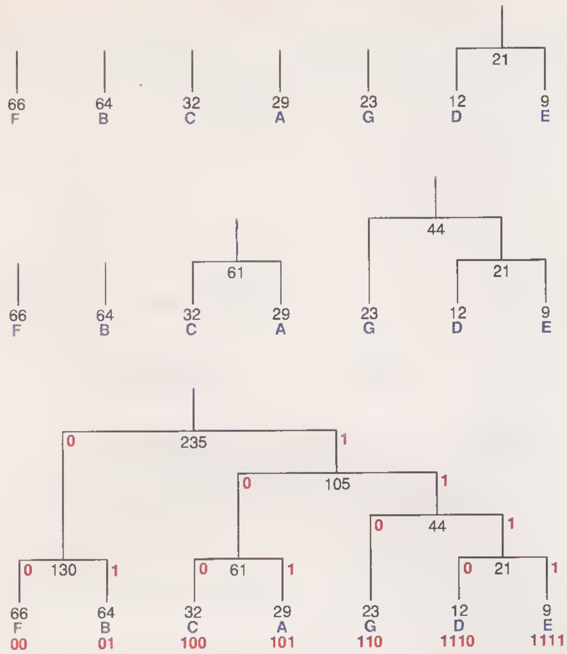


[1] A Huffman tree ensures that its longest branches represent the least-frequent symbols. Building such a tree starts with ranking the members of a group in order of their frequency of occurrence [top]. (Note, in this example, the letter frequencies are not the same as for English in general.) Next, the two least-frequent letters [D and E] are combined in a subgroup whose frequency is the sum of its component frequencies. Out of the remaining letters and one subgroup, the two with the lowest frequencies are again combined. This time, they are the D-E group just formed plus the letter G. Since that combination adds up to 44, the next subgroup will be C and A, which are both less than 44. The process continues until all the letters have been combined into a single group.

But how can one encode a symbol of 0.074 bit? Bits are indivisible, after all, which is one reason that few coding techniques achieve true entropy. Most of them lose a fraction of a bit in efficiency for each symbol encoded.

There are ways to get around that problem, but first, let us take a look at perhaps the simplest method for lossless compression, run-length encoding.

000000000. Run-length encoding is effective whenever a particular character is repeated many times in succession. Instead of repeating the character, run-length encoding uses an escape sequence to specify it and how many times to repeat it. The repeated character is replaced by an escape character followed by 2 bytes: the byte for the character to be duplicated, and a byte specifying how many times to repeat it. Using run-length encoding, the 33-byte sequence ***************************abcdefg* reduces to *<Esc> * 26 abcdefg*, which is only 10 bytes long.

As it stands, however, this scheme, has two potential drawbacks. For one, an escape character may actually occur in a data stream. The answer is to represent it as a consecutive pair of escapes. Of course, the decompression algorithm must be designed to interpret a sequence of two escape characters as a single <Esc>, not as the start of a run-length–encoded sequence.

The other drawback is that a single byte cannot specify run lengths greater than 256. How then are longer runs handled? The solution is to send them as multiple escape sequences; the compression ratio will still be huge.

Run-length encoding is effective only in applications involving many repeated characters. Examples are long strings of 0s or asterisks (often employed in creating borders) and black or white pixels in scanned images. Run-length coding is used most often as a preprocessor for other compression algorithms.

A more sophisticated compression algorithm is the Huffman coder, which tries to assign the most economical possible variable-length bit string to each symbol in an alphabet. Its goal is to see that symbols that occur often are assigned very short codes while the rarer symbols get many more bits.

HUFFMAN TREE. To see how Huffman coding works, assume that a message is to be encoded and that analysis of previous messages shows the following letter frequencies: 66 *F*s, 64 *B*s, 32 *C*s, 29 *A*s, 23 *G*s, 12 *D*s, and 9 *E*s. The first step is to order the letters from highest to lowest frequency of occurrence, which is proportional to the probability of occurrence [Fig. 1, top]. Next, the two least-frequent letters are combined and their frequencies added to find the frequency for the combination. In this case, the *D* and the *E* have a combined frequency of 21.

Next, combine whichever two nodes now have the lowest frequencies—in this case the *G* and the *D-E* pair. That grouping has a combined frequency of 44, so for the third iteration, they are passed over, and the *C* and *A* are combined [Fig. 1, middle].

This procedure is repeated until all the letters have been combined into a single structure called a Huffman tree [Fig. 1, bottom]. Then each branch of the tree is labeled with a *0* or *1*. How the bits are assigned is not important as long as the assignments are consistent. In this case, the left-hand branches are *0*s and the right-hand ones are *1*s.

To create the Huffman code for a given letter, the tree is traversed from that letter to the root, and the order of the bits is reversed. Thus, the letter *F* is coded as *00*, *A* is *101*, and *D* is *1110*. The most likely letters are on the shortest branches and so are encoded with the fewest bits, while the least likely ones are on the longest branches and use the most bits.

The method of constructing Huffman codes ensures that symbols

Letter	Probability	Range
a	0.1	0.0–0.1
i	0.1	0.1–0.2
l	0.2	0.2–0.4
m	0.1	0.4–0.5
n	0.1	0.5–0.6
o	0.2	0.6–0.8
p	0.1	0.8–0.9
y	0.1	0.9–1.0

Letter	Range	Interval width	Interval after encoded symbol
			0.0–1.0
p	0.8–0.9	1.0	0.8–0.9
o	0.6–0.8	0.1	0.86–0.88
l	0.2–0.4	0.02	0.864–0.868
y	0.9–1.0	0.004	0.8676–0.8680
n	0.5–0.6	0.0004	0.86780–0.86784
o	0.6–0.8	0.00004	0.867824–0.867832
m	0.4–0.5	0.000008	0.8678272–0.8678280
i	0.1–0.2	0.0000008	0.86782728–0.867827360
a	0.0–0.1	0.00000008	0.867827280–0.867827288
l	0.2–0.4	0.000000008	0.8678272816–0.8678272832

[2] Arithmetic coding circumvents the problem of bit fractions. In using it to send the word "polynomial" the component letters are first assigned probabilities derived from experience, although in this example the probabilities reflect the message word itself. Then each symbol is assigned a unique range in the interval from 0 to 1 whose width is equal to its probability of occurrence [top]. The process of compressing the message consists of progressively narrowing the arithmetic interval as each symbol is added. Initially, the interval width is 1. After the first letter, p, is encoded, it is reduced to 0.1. Adding the o further reduces it to 0.02, and so on as the various other letters are added to the message [bottom].

will not be confused during decompression. The "prefix" of one symbol will never be a unique symbol in itself. In the example above, *D* is represented by *1110*. The method of construction ensures that the prefixes *1*, *11*, and *111* are not discrete higher-probability symbols. The prefix property simplifies decoding and eliminates the need to explicitly delimit variable-length symbols.

The value of these two coding methods is beyond dispute. Fax machines use a combination of run-length and Huffman encoding to achieve a compression ratio of about 10:1.

ADAPTIVE HUFFMAN. In the previous Huffman example, the frequency at which a given symbol was seen dictated the number of bits needed to encode it. Symbol probabilities were static, based upon an *a priori* analysis of a body of data. Static Huffman codes are appropriate where probabilities are reasonably constant or where error correction is impractical. Compression ratios can be greatly improved, however, if the Huffman tree is allowed to adjust itself to the probability distribution of the data being sent.

With adaptive Huffman coding it is not necessary for the updated tree to be explicitly sent from the transmitting end of the communications link to the receiving end. Instead, the receiver executes the same tree-updating algorithm as the transmitter. As long as errors are not introduced between the encoder and decoder, both trees will evolve identically.

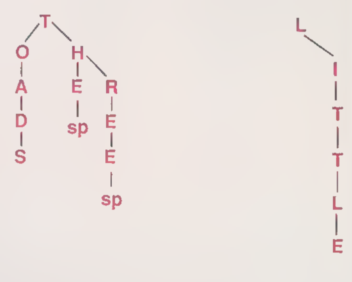
ARITHMETIC CODING. The number of bits required to encode each symbol in a Huffman code is a whole number. But what if, based upon entropy, a symbol requires only 0.5 bit to encode? In the Huffman case, at least one bit must be emitted for this symbol. Arithmetic codes were developed to overcome the fractional-bit deficiencies of Huffman codes. While they are more complex to implement, recent theoretical work has made implementing them practical on conventional processors.

Arithmetic coding achieves optimal encoding by merging the probabilities of many symbols into a single high-precision fraction for transmission as the compressed message. Accordingly, the objective is to determine a fraction in the range from 0 to 1 that accurately represents all the symbols in a given message. This fraction is carefully constructed so that it may be decoded unambiguously.

Initially, the probabilities of the symbols in the alphabet are determined by how often they occur in a body of text, with the total probability for all symbols set at 1. Each symbol is then assigned a range on the fractional number line from 0 to 1. While the positions of the various ranges are arbitrary, they must not overlap, and their widths must be equal to the probabilities of the symbols they represent [Fig. 2, top]. Note that the same information must be available to the decoder.

Before any symbols are encoded, the message interval width is 1. As each symbol is encoded, the message interval width is reduced to a new subinterval inside the range of the current symbol's range on the old interval.

This is done by multiplying the width of the current message interval by the upper and lower bounds of the range of the symbol to



[3] In LZ-78 coding, strings are specified simply by pointing to the nodes at which they terminate. Thus, pointing to the letter **S** *at the lower left specifies the entire word* **TOADS**. *If a trie (pronounced "try") has N nodes, each can be specified by an M-bit pointer, where $M = 1 + \log_2 N$. The extra bit is a flag that distinguishes coded from uncoded data. In the phrase* **THE THREE LITTLE TOADS**, *a space follows* **LITTLE**, *but does not follow it in the trie. Hence, the space symbol would be sent uncoded, but preceded by a flag bit indicating that it is not a node identification number. The hard part of implementing LZ-78 is deciding how to build up the dictionary trie.*

be encoded and then adding the results to the lower bound of the current interval. The subdivision of the message interval continues until all the symbols of a message are encoded [Fig. 2, bottom].

Once the message is encoded, it may be transmitted as any value that lies within the final message interval. At first sight, that looks impractical since computers have limited precision, and will overflow after just a few symbols. But this is not really a problem, since the encoded message need not be stored and transmitted all at once. As soon as the most significant (leftmost) digits in the upper and lower boundaries become equal, they are guaranteed not to change as additional symbols are encoded. Thus they may be transmitted, and the remaining fraction shifted left to occupy the vacated positions.

To indicate to the decoder that the end of the message has been reached, an end-of-message symbol is usually added to the message alphabet.

TRIE-BASED CODES. Good as they are, the Huffman and arithmetic models are less than efficient at modeling text because storage constraints keep them from capturing the higher-order relationships between words and phrases. Far more effective are two simple string-matching techniques, known as LZ-77 and LZ-78, which find and eliminate the redundancy in repetitive strings. These techniques were invented by two computer scientists, A. Lempel and J. Ziv, in 1977 and 1978.

LZ-77 exploits the fact that the words and phrases within a text stream are likely to be repeated. When they do occur, they may be encoded as a pointer to any previous occurrence plus a field indicating the length of a match. When there is no match, an escape bit may be used to indicate that a noncompressed character follows.

Key to the operation of LZ-77 is a sliding history buffer, which stores the text most recently transmitted. When the buffer fills up, its oldest contents are discarded.

Text in → $\boxed{\text{Sliding history buffer}}$ → Discard

Clearly, the size of the buffer is an important system parameter. If it is too small, finding string matches will be less likely. If it is too large, pointers to matches in the buffer become large enough to adversely affect the compression ratio.

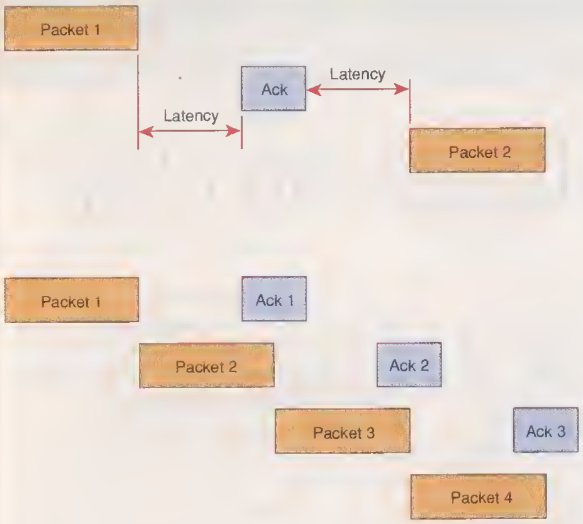
With LZ-77, the beginning of the encoding process looks like the transmission of uncoded data since there are no previous occurrences of any strings to be pointed to. Consider the nonsense phrase **the brown fox jumped over the brown foxy jumping frog**, which is 53 bytes long. Each character at the start is preceded by a 1-bit header (1), which indicates that the byte that follows is an uncoded character. The nonsense phrase thus begins, **'t'h'e' 'b'r'o'w'n' 'f'o'x' 'j'u'm'p'e'd' 'o'v'e'r'** , which is 234 bits long, including the space at the end (26 characters, each of which is 9 bits long, including its 1-bit header).

The next part of the message does contain some repetition, so it may be encoded as a pointer and a length field. To further improve the scheme's efficiency in this example, assume two options at this point—an 8-bit pointer and a 4-bit length, or a 12-bit pointer and a 6-bit length. A 2-bit header indicates which option is being used, with 00 indicating the first, and 01, the second.

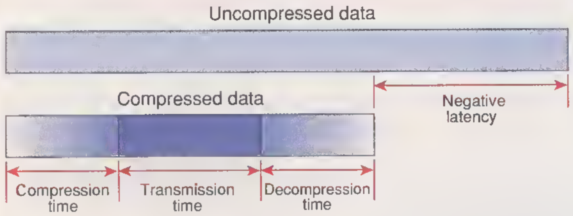
The next part of the message (**the brown fox**) thus reads, $<00_b><26_d><13_d>$, where $<00_b>$ is a 2-bit binary header; $<26_d>$ is an 8-bit binary pointer with a decimal value of 26, indicating that the encoded character string begins 26 characters back; and $<13_d>$ is a 4-bit binary number with a value of 13 that specifies the length of the matched string as 13 characters. This part of the message is 14 bits long: the 2-bit header, the 8-bit pointer, and the 4-bit length field.

The three remaining parts of the message are: **'y**, which must be sent as a literal because it has not occurred before; $<00_b><27_d><5_d>$, which represents a space followed by the word "jump"; and **'i'n'g' 'f'r'o'g**. As before, the encoded string $<00_b><27_d><5_d>$ indicates that the string to be represented is five characters long and begins 27 characters back.

The **'y** is 9 bits long, the encoded string **(space)jump** is 14 bits long, and the final string is 72 bits, for a total encoded message



[4] In a nonwindowed protocol environment [top], packet 2 cannot be sent until packet 1 has been acknowledged. Since that involves two latencies, transmission is slowed down. With a windowed protocol, packets are sent continually, overlapping the link latency [bottom].



[5] More is less. Even though it takes time to compress and decompress data, compression can nevertheless reduce transmission time because it reduces the amount of data to be sent.

length of 343 bits, or slightly less than 43 bytes.

This technique works best with moderate-size dictionaries of 2 kilobytes or more, typically compressing text to a third or less of its original length. The hardest part of it to implement is the rapid search for the best match in the buffer. Most implementations use binary trees, hash tables, or (for maximum speed) content-addressable memories.

LZ-78 ALGORITHMS. Unfortunately, when data passes out of the sliding history buffer, it is no longer useful. The LZ-78 algorithm attempts to overcome that LZ-77 limitation with a greedy match-and-grow algorithm.

To do so, it employs a data structure known as a trie (from retrie-val), which is often used for implementing dictionaries [Fig. 3]. Pointing to a trie node at the end of a phrase is enough to encode the entire phrase. The decompressor, which, of course, must have an identical trie, parses backwards from the reference node to the root node to decode.

When a string is too short to be efficiently specified as a node, its first character is sent in uncoded form preceded by an escape symbol to indicate that it is not encoded.

Figure 3 indicates how LZ-78 works. The string **THE THREE LITTLE TOADS**, which is represented there by part of a trie, can be encoded from the trie in four pointers plus one space. First, a pointer to the space following **THE**; then a pointer to the space following **THREE**; next, a pointer to the **E** in **LITTLE**. At this juncture, a space is needed, which is most efficiently encoded as a flag bit followed by a space. Last comes a pointer to the **S** in **TOADS**.

Assuming that the trie of Fig. 3 is only part of a larger dictionary with a total of 32K nodes, each node can be specified with 16 bits—15 to identify the node plus a flag bit, which distinguishes between trie node identification numbers and uncoded data.

The original phrase contained 22 bytes. The encoded version consisted of four 16-bit pointers plus a single 9-bit character (8 bits plus a flag bit) for a total of 73 bits, or 9 bytes.

WAN APPLICATIONS. An area to which compression has a very large contribution to make is the wide-area network packet-based environment. Now if the most effective compression algorithms dynamically adapt to the statistics of the data being processed, for both ends of the link to remain synchronized, it is essential that no errors be introduced between the encoder and the decoder.

Consider LZ-77. If a message is lost or damaged in transit, then subsequent references to the data it contains will be improperly decoded. Most WAN compressors use X.25 LAPB procedures to ensure an error-free link. LAPB retransmits frames found to have been damaged by the remote receiver.

Some WAN compressors simply resynchronize their dictionaries when packets are lost or damaged because of line errors. The unfortunate consequence is the loss of dozens or perhaps hundreds of packets while the units resynchronize themselves. Though higher-level protocols will retransmit lost packets, doing so takes several seconds, which means that throughput falls off dramatically in the presence of even moderate bit-error rates.

THROUGHPUT AND LATENCY. In packet-based data-compression applications, data must be compressed and recovered in real time without adding substantial latency to data transfers. Many LAN and WAN protocols are highly sensitive to latency because they are not windowed or have only limited windowing capabilities.

Windowed protocols allow multiple packets to be outstanding on a link before an acknowledgment is required. Nonwindowed protocols require an acknowledgment to be returned for every packet before the next one can be sent. Therefore every packet incurs a roundtrip delay. Throughput suffers since the latency associated with each compression and decompression is exposed.

In windowed protocols, in contrast, the compression and decompression latencies are able to overlap packet transmission [Fig. 4]. But even when a windowed protocol such as TCP/IP is used, the window size is often not configured to a very large value. This tends to limit the degree of overlap under high-latency conditions.

Due to latency considerations in applications with little or no windowing capability, hardware-based compression solutions outperform those based on software or firmware, even when they implement the same algorithm.

With a hardware-based pipelined compression and transmission architecture, latency may even be negative. In other words, the end of a decompressed packet can arrive at its receiver sooner than it would if it were not compressed. The start of reception for decompressed packets is delayed by the latency of the compression and decompression pipelines. This delay is more than compensated for by a reduction in transmission time resulting from reduced packet sizes [Fig. 5].

TO PROBE FURTHER. Robert Lucky's book, *Silicon Dreams* (St. Martin's Press, 1989), is a very readable exposition of data-compression technologies. Jiri Adamek's book *Foundation of Coding* (John Wiley & Sons, 1991) is a good introduction to coding theory and compression. In *The Data Compression Book* (M&T Books, 1991), Mark Nelson provides clear explanations and examples in C of common compression algorithms. T.C. Bell, J.G. Cleary, and I.H. Witten's *Text Compression* is a more rigorous examination of basic algorithms for text compression. William Pennebaker and Joan Mitchell's *JPEG Still Image Data Compression* (Van Nostrand Reinhold, 1993) provides the basics of still-image compression. ◆

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Mixing signals & voltages on chip

The rapid development of personal communications is driving the integration of 3- and 5-V analog and digital circuitry on a single chip

Modems, faxes, computer networks, and databases are no longer viewed as luxuries in modern offices and laboratories. They are seen as essential tools, which are often portable and soon to be wireless ones, at that. This is one reason for the growing demand for still denser, mixed-signal circuitry that operates at low power. A concurrent trend in chip lithography is submicrometer features, which easily overheat and therefore also must be operated at low power. To most system-design engineers, these developments in application-specific ICs (ASICs) are uncharted waters.

Traditionally, for instance, disk-drive design has kept analog and digital functions apart. But today's smaller disk drives, the 1.8-inch and 1.3-inch types found in notebook and palmtop computers, integrate analog-to-digital converters with digital circuits in an ASIC. By one estimate, the simplified chip set reduces chip count by 40 percent, cutting circuit board area and system weight, size, and cost.

Further off in the future, one popular view of personal communicators has them seamlessly integrating voice, data, handwriting, fax, electronic mail, still images, and full-motion video [Fig. 1]. All functions are slated to be performed wirelessly, thus handing the user anytime, anyplace, and any-medium communications.

As for lower power, reducing the supply voltage from today's 5 V to 3 V can lop two-thirds off power consumption, extending battery life. More fundamentally, as minimum chip geometries edge below 0.5 μm, 3 V becomes a necessity; lines as narrow as that would be overheated by high-frequency signals, and if used on a 5-V chip with a high gate-count, would downgrade reliability. In addition, expensive ceramic packaging would be needed to handle the large amount of power generated.

Lauren Brust and Mean-Sea Tsay
AT&T Bell Laboratories

It is only a matter of time before silicon chips that operate at 3 V and combine both analog and digital circuitry [Fig. 2] become a new norm. For engineers who have honed their skills on 5-V digital design, the good news is that, in most instances, some design basics will continue to apply. The not-as-good news is that they will need to acquire a good understanding of the pitfalls in three areas: low-voltage digital circuitry, mixed digital and analog technology, and mixed-voltage circuit design. As the box on p. 42 shows, the engineering issues associated with 3-V mixed-signal design are numerous.

ON YOUR MARK. The 3-V chip race started in 1992. If the conversion of 5-V ASIC libraries to 3-V designs is done properly, it takes six months to a year [Fig. 3]. But the speed with which some devices appeared on the market suggests that they may not have been fully characterized for operation at the lower voltage. In some instances, hasty revisions seem to have been made to 5-V designs. One possible shortcut to 3-V digital ASICs is to reduce the power supply voltage on existing 5-V silicon. Another shortcut is to recharacterize 5-V cells as 3-V versions by applying an average derating factor on all gates and logic cells alike.

Careful designers of 3-V circuits heed the rule: not all gates and logic cells are created equal. The delays of various cells do not necessarily track as the power supply is scaled from 5 V to 3 V. To ensure effective operation of the circuit, all cells must be fully characterized at 3.3 V and even down to 2 V. Otherwise, they can tilt a design toward lower-than-expected performance and ultimate failure in a system or both. What is effective at a higher voltage need not operate efficiently at the lower ranges.

> In some instances hasty adjustments to 5-V designs may have been made to bring 3-V versions to market quickly

As the voltage is scaled down, two-input NOR and four-input NAND gates decline in performance at a faster rate than do inverters and two-input NAND gates. The four-input NOR is the poorest, with its performance falling rapidly below 3.5 V. In low-voltage applications, four-input gates should be avoided whenever possible.

The smaller transconductance of the p-channel pullup transistor (vis-à-vis the n-channel device) contributes heavily to performance degradation at a lower voltage. The effect is more pronounced in NOR gates, less so in NAND gates. A NOR gate includes two or more p-channel devices in series, an arrangement that compounds the effect. In the NAND gate, however, the p-channel pullup transistors are in parallel, so that the problem is minimal and performance can be higher at 3 V.

A high-drive four-input NOR gate with twice the drive capability of a regular four-input NOR can be used to regain some performance in critical paths. The penalty is an increase in area and power. But this price is more than offset by the power saved from reducing the operating voltage to 3 V, since power varies linearly with capacitance but with the square of the voltage. In some critical paths containing large capacitive loads, designers can buy back the necessary performance by judicious implementation of 3-V BiCMOS cells. But for critical paths with many gates in series and small loads, BiCMOS may not help.

The correct way for vendors to accurately characterize 3-V logic cells and gates has two steps. First, power supply limits are selected in which the cell library can operate effectively. (It is also within these limits that a cell library is expected to be simulated accurately.) Second, each cell has to be individually and fully characterized over voltage, temperature, and process-parameter ranges. This data must be included in cell models to ensure the highest levels of simulation accuracy.

It is also important for the chip vendor to include in chip-level simulation such effects as voltage, temperature, and process-parameter variations. With accurate library descriptions, the logic designer can then calculate delays associated with either a 5-V or 3-V environment.

When 5-V and 3-V circuits are mixed on a chip, simulation challenges multiply. Additional cells, which shift the signal level, have to be incorporated in order to smooth the interface between the 5-V and 3-V sections. For 3-V-only technologies, the I/O buffers that interface with the 5-V environment can

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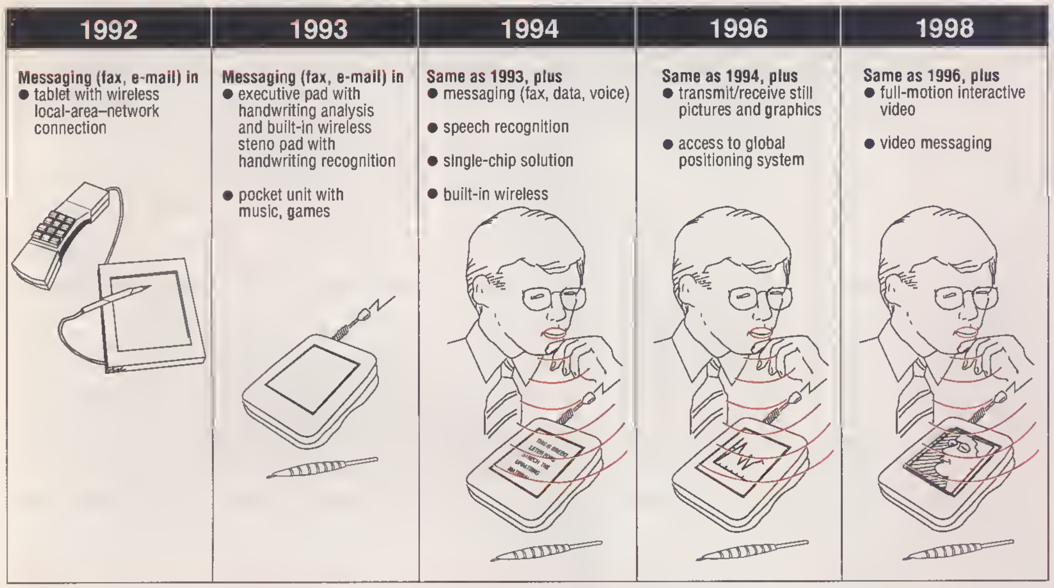
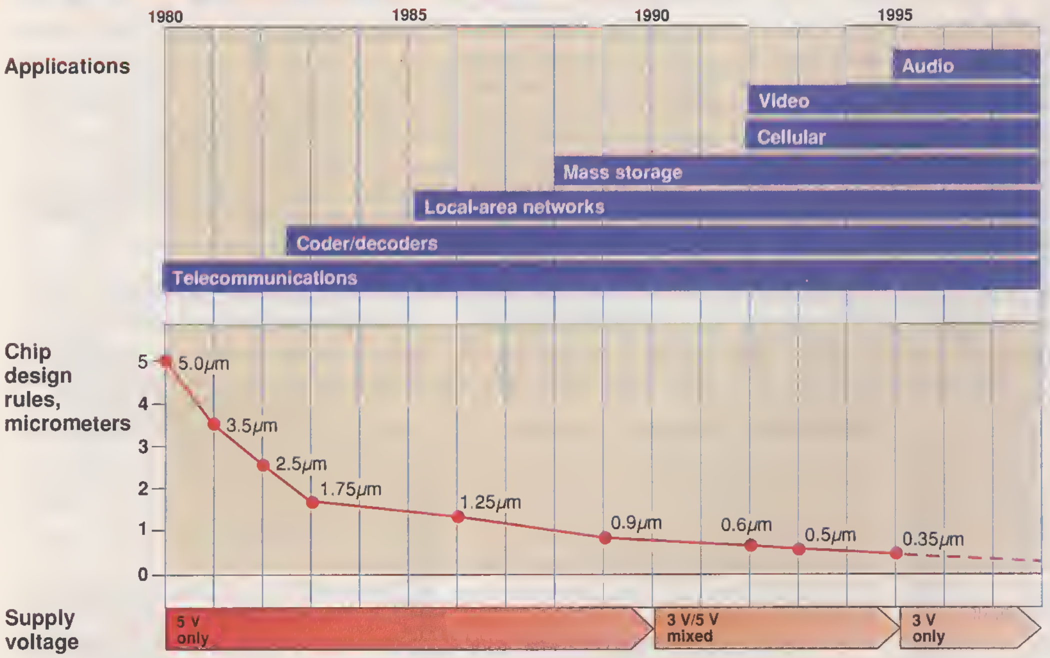
Evolution of the personal communicator



[1] A look into the future of the personal communicator sees voice being integrated on one chip with data, fax, video, electronic mail, and eventually video messaging. The AT&T EO 440, a unit offering fax, e-mail, voice communications, data access, and pen-based computing is available from EO Inc., Mountain View, CA, or through the AT&T Phone Centers. Depending on options, the cost is between $2000 and $4000.

Mixed-signal applications and technology trends



[2] Chip feature sizes are almost one-tenth the size that they were in 1980, and the trend is continuing. The narrower lines and thinner oxides associated with the shrinking dimensions require lower power levels. Additionally, the higher levels of integration are making mixed-signal ICs attractive.

be very difficult to design. The thin gate oxide of a MOSFET fabricated for 3-V operation cannot tolerate 5 V. Therefore, special circuit design tricks or extra process steps may be required. Limitations of existing simulation and layout computer-aided design (CAD) tools pose another problem. Without enhancements, these tools cannot easily handle both 5-V and 3-V sections on the same chip.

ENTER ANALOG. When it comes to simulating analog circuits, accuracy counts for even more than with digital circuits. In fact, accuracy is to analog circuitry what speed and performance are to digital circuits. Many analog circuits designed for 5-V operation do not work properly in the 3-V region. Often, they have to be redesigned and resimulated.

The three key aspects involved in accurately characterizing 3-V analog cells are: modeling, simulation, and design tolerance evaluation.

A MOSFET transistor model is essential for analyzing and designing high-performance analog circuits fabricated in submicrometer CMOS technologies. The model must be accurate in the triode, saturation, and subthreshold regions, with smooth transitions between these three regions.

Advanced models for analog simulation are based on charge conservation, whereas most digital simulation uses capacitance-based models. Charge conservation prevents node voltages from drifting over time because of coupling between nodes. Otherwise, dramatic changes may occur in analog circuit simulations, although node coupling has virtually no effect on digital circuit simulations.

The single-piece equation that describes the triode, saturation, and subthreshold regions is the other important feature of an accurate transistor model. Where separate equations are used for each region, as in some commercially available models, anomalous effects, known as kinks and glitches, occur in the transistor source-drain current, transconductance, and output conductance at the boundaries between regions.

After the transistor model comes the analog circuit simulation model. It is generated automatically following design and layout of the transistor schematic. All the information necessary on parasitic components is extracted from the physical lay-

3-V mixed-signal design issues

- Designing for dual 5-V and 3-V application
- Designing mixed 5-V and 3-V chips
  - 5-V I/O with 3-V core
  - Mixed 5-V/3-V cores
- Netlist audits for proper interfaces
- High-speed design (greater than 50 MHz)
- High-speed clock distribution
- Thermal constraints of plastic packages
- Over-voltage protection
  - 3-V chips with 5-V inputs
- Low-battery detection
- Analog/digital interface
- Reduced signal-levels
- Operating-voltage specification
- Noise sensitivity
- Testability
- Cost: digital vs. analog processing
- Understanding new architectures
- I/O compatibility with 5-V and 3-V chips
- Accurate analog simulation
- Mixed-signal simulation

out to structure the circuit model. Included here are transistor sizes, routing capacitances, inter-node coupling capacitances, and sizes of the parasitic diodes. Details like these are vital to simulation accuracy.

Lastly, design tolerance must be evaluated during and after the fabrication of the chips to guarantee analog accuracy. This is done by analyzing large groups of finished silicon wafers representing best-case fast, nominal, and worst-case slow conditions and with various parasitic loadings. During fabrication, chip parameters such as channel length, channel width, gate oxide, and dielectric thickness are systematically varied. Afterward, devices with different parameter sets are characterized, with the goal of generating accurate specifications that cover all extremes in processing, voltage, and temperature. Also to be taken into account in characterizing the circuits is correlation between parameters, such as between the channel lengths of p-type and n-type field-effect transistors (FETs).

TOWARD SUPER MACROS. Mixed-signal circuitry is making an early mark in communications applications such as the Ethernet interface analog macrocell. This heralds a higher level of system integration on a chip. But it also points up several universal issues relating to design with analog macrocells. They deal with specifications, behavioral models, and circuit simulation.

Complete and acceptable specifications can only be produced if system designers work jointly with macrocell developers. This means covering every I/O pin and providing set-up-and-hold, minimum-pulse-width, minimum-and-maximum-period information on each and every pin. The system designer must therefore be familiar with system operation, and especially with how the large macrocells work with adjoining functions.

Close attention must also be paid to crucial specifications. For example, in many advanced systems, the minimum pulse width may be critical for determining whether or not a system operates efficiently.

In circuit simulation, phase-locked loops (PLLs) with their internal feedback loops pose special problems, especially when analog signals are converted into digital. A good illustration is the Ethernet macrocell, which has two PLLs in the Manchester encoder/decoder. The output from the chip's internal voltage-controlled oscillator (VCO) is compared with the Ethernet macrocell input signal. If they differ in frequency, a signal is generated and fed back into a low-pass filter, for filtering into a slowly varying analog control voltage, which changes the VCO frequency. After many cycles (the lock-in time), the VCO acquires the same frequency as the Ethernet macrocell input signal.

By its very nature, this feedback system makes trouble for PLL design verification. The designer cannot directly measure the internal analog control voltage since it is not possible to "break" the decoder's feedback loop and apply an analog input stimulus. Instead, a variety of input frequencies must be used to test the characteristics of each PLL circuit to make sure the output digital values are correct.

Almost as burdensome is the amount of computer time required to simulate a PLL. Typical transistor simulation has time steps that are fractions of nanoseconds, while PLLs typically have lock-in times of microseconds. Consequently, a transistor-level simulator would have to operate for days to simulate lock-in time.

MIXED-SIGNAL SIMULATION. Integration of analog cells onto digital ICs complicates simulation further. While digital chips are usually simulated with precharacterized cells, analog cells are simulated in more detail, down at the transistor level. Simulating both types of cell on the same chip takes some ingenuity.

For instance, the function of an analog cell can be represented by extra digital gates attached to the analog cell. Then, the analog cell can be bypassed, and only its digital representation used in the chip simulation. The analog cell still needs to be simulated, but it can be treated in a stand-alone manner.

A more formal way to simulate analog and digital sections side by side is to use mixed-mode simulation tools. A variety of such tools are on the market, but the costs are higher than for the simpler method described above.

Some mixed-signal simulators, particularly the earlier ones, simply glue together separate analog and digital simulation programs. But the need to maintain multiple databases and syntaxes degrades their performance and makes them cumbersome to use. Within the current generation of offerings, though, are integrated products that tightly couple the analog and digital simulation engines, allowing both portions of the design to be contained in the same circuit model. Hardware-description language support is now available for the digital portions, which makes the top-down design of mixed-signal circuits a lot easier to do.

Mixed-signal simulators are available in a range of prices. Many of the less expensive ones run with DOS on a PC platform and are adequate for simpler circuits. The more expensive products operate on workstations, but can simulate complex systems with great efficiency.

TESTING. The testing of mixed-signal ASICs is of course in its embryonic stage. While procedures and equipment for testing stand-alone digital or analog chips are well established, the same is not true for mixed-signal chips. Most digital testers cannot be used to test analog functions easily or thoroughly. One reason is that signals supplied by digital testers are typically step functions, while analog circuits often require ramped or sinusoidal signals. On the other hand, analog testers do not generally accommodate the high pin-counts of many digital chips. But as before, special techniques can ease the difficulty.

Test circuits should be planned ahead and included in the design phase before analog functions are integrated with digital sections. During testing of digital sections,

Defining terms

Ethernet: a local-area–network architecture that transmits data at a rate of 10 Mb/s on twisted-pair or coaxial cables and operates on a contention-based control protocol.

Local-area network (LAN): a system linking computers, word processors, and other electronic office machines within one site.

Lock-in time: the amount of time required for the voltage-controlled oscillator to acquire the frequency of the input signal.

Macrocell: a block of uncommitted logic circuits made up of small standard cells.

Mixed-signal circuit: one in which two portions of an IC chip handle analog and digital signals, frequently found in communications applications.

Operating voltage: the voltage at which a circuit element operates. This may or may not be equal to the supply voltage.

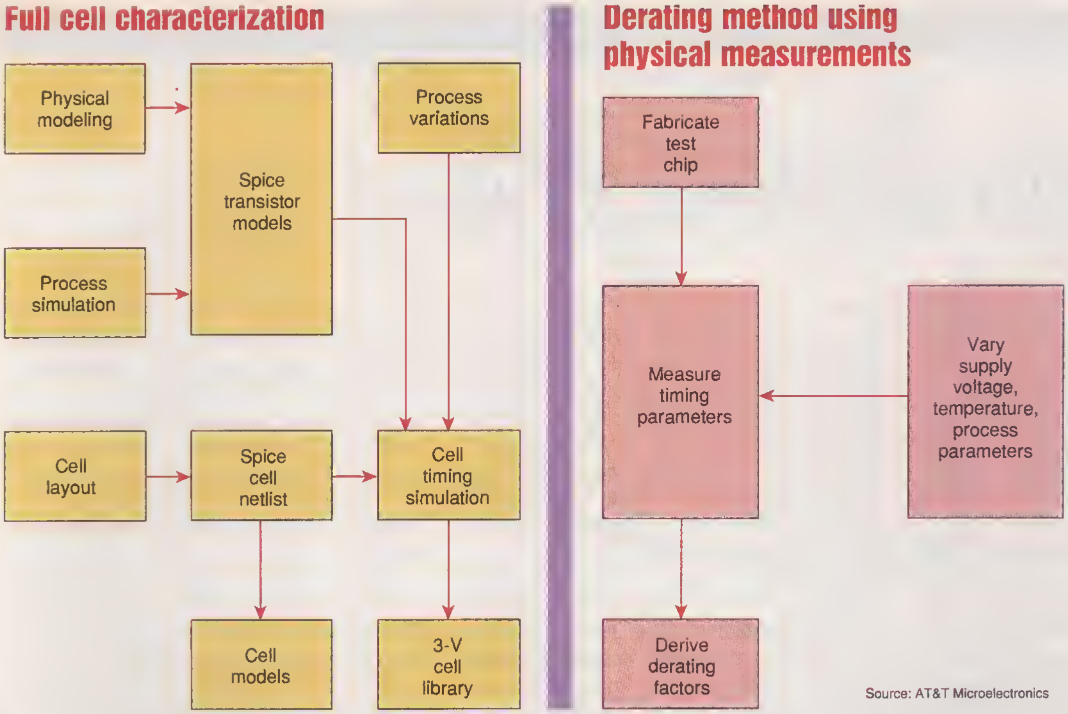
Phase-locked loop (PLL): a circuit that synchronizes the phase and frequency of a local oscillator with that of an input signal.

Pullup transistor: one that, when turned on, pulls the output of a circuit up to the operating voltage.

Supply voltage: the voltage supplied to a chip from an external power source.

Transconductance: the ratio of the change in drain current to the change in gate voltage when drain voltage is kept constant.

Voltage-controlled oscillator (VCO): one in which the output frequency is a function of an input signal.



[3] The basic process for developing a 3-V or 5-V cell library starts with a Spice-like netlist, transistor models, and the effects of process variations. From this input, cell-level timing is extracted and used to automatically develop delay equations for each cell, in either the 3-V or 5-V environment.

analog circuits can be bypassed if multiplexers are provided. Then, if hooked up to some additional analog equipment, many digital testers can be modified slightly to test most of the important analog specifications. To test an analog-to-digital converter circuit, a digital test machine should include a digital pattern generator, a high-precision digital-to-analog converter for providing analog stimulus, and a digital signal-processing device for analyzing the test data.

Analog testers should be used to fully characterize the analog functions. This can be done during the design tolerance evaluation phase, when the analog functions are designed and tested in a stand-alone fashion, and before integration into ICs. This procedure should satisfy the production testing needs for most of the mixed-signal ICs. As mixed-signal designs become more common, so will testers designed specifically for measuring these devices.

Not to be overlooked, finally, is the noise sensitivity of analog circuits. Inside a packaged IC, noise amplitudes of a few hundred millivolts are common and unless care is taken, can interfere with the operation of analog circuits placed next to digital sections. Noise immunity is often secured by including differential-mode circuits, power/ground bus isolation, and shield-building in mixed-signal designs.

Design concerns like these are here to stay as mixed-signal circuitry grows more complex. System-level, mixed-signal solutions are absorbing major computing and communications functions into the same piece of silicon.

Moreover, heterogeneous integration, the implementation of several applications on a chip, will exert more pressure for smaller size, higher performance, and lower system cost. One example attracting increasing interest is the combination of local-area network communications with such wide-area network communications as modems and faxes into single solutions, first at the board level, and eventually in a single chip. For all its problems, This new approach does enable engineers to develop innovative applications in automotive and medical electronics, communications, and multimedia.

TO PROBE FURTHER. A basic text on analog circuits is provided in the second edition of J. Michael Jacob's *Applications and Design with Analog Integrated Circuits* (Regents/ Prentice Hall, Englewood Cliffs, NJ, 1993).

> Testability and noise immunity need special attention when digital and analog circuits are combined in an IC

An excellent introduction to analog/digital converters is J. Michael McMenamin's *Linear Integrated Circuits: Operations and Applications* (Prentice Hall, Englewood Cliffs, NJ, 1985).

An up-to-date and thorough discussion of phase-locked loops is the book *Phase-Locked Loops: Theory, Design, and Applications*, now in its second edition, by Roland E. Best (McGraw Hill, New York, 1993). A bonus is a floppy disk that readers can use to look at the performance of a PLL circuit as if they were checking waveforms of a breadboard circuit with an oscilloscope. Additional information can be found in *Phaselock Techniques*, second edition, by Floyd Martin Gardner (Wiley, New York, 1979), and *Phase-Locked Loops: Application to Coherent Receiver Design*, by Alain A. Blanchard (Wiley, New York, 1976).

A number of technical discussions of low-power designs of CMOS and BiCMOS circuits can be found in the April 1992 issue of the *IEEE Journal of Solid-State Circuits*, Vol. 27.

Two recent reviews of mixed-signal design issues are *Mixed-Mode Simulation*, by Resve A. Saleh and A. Richard Newton, and *Introduction to Analog VLSI Design Automation*, edited by Mohammed Ismail and Jose Franca (both from Kluwer Academic Publishers, Norwell, MA, 1990).

Several recent articles in *IEEE Spec-trum* have covered aspects of low-voltage, mixed-signal circuits. John Williams considered the questions arising from the mixing of 3-V and 5-V ICs in the March 1993 issue, pp. 40–42. In May 1992, Betty Prince and Roelof H.W. Salters reviewed the driving forces behind the trend to lower-voltage ICs, pp. 22–25. Various issues of the computer-aided design of mixed-signal circuits were covered in November 1992, pp. 49–51, by Ramesh Harjani. ◆

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Competitive intelligence

The Japanese are practiced players at the game of technology intelligence—a skill that will be key to corporate success in the '90s

Toshiba Corp. had a successful business in 16K dynamic RAMs (DRAMs) but was never more than a minor player in the 64K market. When it sought a comeback, it took a close look at its competitors and saw they were focusing on the next generation of products—256K memories—but had yet to look beyond to the 1M generation. Accordingly, Toshiba chose to emphasize research in 1M DRAMs and blindsided its rivals several years later when it emerged as a leading player in the 1M-DRAM market.

Likewise, when Japanese manufacturers of blank videotape sought to capture the tape-making business from their Western competitors, they openly asked videocassette recorder manufacturers what features they would like to see that were currently lacking in videotape products. Armed with that information, the videotape makers launched a co-development project with a Japanese manufacturer of the plastic tape substrate. Their advanced videotape left Western companies in the dust.

These successes were not due to prescient management. Rather, they were the fruits of resources plowed year after year into worldwide information gathering—competitive intelligence.

Competitive intelligence involves collecting, analyzing, delivering, and using publicly available information on activities outside the company's walls. In any world-class company, competitive intelligence, built into the business system, can improve R&D effectiveness, support management decisions, and provide early warnings of threats to the company's business. It has become a critically important tool in gaining an edge in competitive global markets.

Atsuro Kokubo
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But as this strategy has become more pivotal, it has become more difficult to achieve. New obstacles have arisen. The leaders in technology are scattered widely throughout the world; knowledge is expanding faster; links among academic, commercial, and governmental organizations are multiplying; and new entrants in the technological business from different industries are changing the rules of the game.

Then, too, obtaining vast quantities of information does not guarantee successful competitive intelligence—it requires skills in collecting appropriate information, boiling it down to its key points, analyzing the implications, and attracting the attention of corporate decision-makers.

For the engineer, competitive intelligence means assessing the competitiveness of his or her own designs and trying to understand where a market is going, who the key players will be, and which technologies will dominate. The intelligence process goes beyond reverse engineering, which is merely a tool for determining the technologies currently used in a competing product. Reverse engineering, however, can be part of the process, if engineers who already understand their competitors' direction use it to improve their insight into the technologies that will drive their industry in the future.

Japan, defeated in World War II partly because of a lack of effective intelligence activities, has become a leader in competitive intelligence. Such information-gathering has been stressed throughout Japanese industry as it has rushed to catch up with overseas opponents after being demolished by the war.

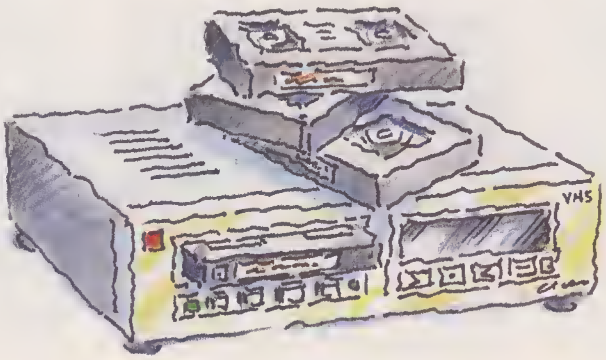
DRAM CONQUEST. In 1982 the leading industrial newspaper in Japan reported, incorrectly, that Toshiba, in Tokyo, had decided to withdraw from the DRAM business. At that time, when the state of the art was the 64K DRAM, Toshiba's share of that market was estimated at just a few percent, which could not justify the company's huge investment in the technology. Few industry experts were surprised by the newspaper announcement, and most thought that such a withdrawal was understandable. Apparently so did Toshiba's competitors, who did not research it further.

The news report turned out to be wrong, for in 1985 Toshiba introduced its 1M DRAM at a yield ratio that was twice the average yields of its competitors. The company quickly dominated the 1M-DRAM market and is now a top player in 4M DRAMs.

Toshiba's success was due in large part to its competitors' carelessness in gathering competitive intelligence. Clearly, Toshiba was hesitating to move into head-on competition in 256K DRAMs and was making special efforts to learn key technologies for 1M DRAM through experimental manufacturing of 256K DRAMs.

This strategy could easily have been spotted, had anyone chosen to carefully and objectively examine the company's technical reports and organizational changes.

Some clues might have come from an analysis of publicly available reports from Toshiba, such as papers delivered at conferences that described various 256K-DRAM manufacturing processes under development in 1982. Toshiba, even at that time, had a corporate policy that could have been called "Challenge to 1M," because in designing its 256K product, it adopted the newest, finer-line technologies as much as possible. In contrast, NEC Corp.'s policy could have been called "Profit from 64K Generation," because the conventional technologies NEC used in 64K-DRAM development were, as much as possible, transferred to the 256K product. Hitachi Ltd.'s program was a mix of the two.



Norm Bendell

Perhaps a more subtle hint could have been discovered in company-issued news releases. While NEC and Hitachi, both in Tokyo, announced huge investments in DRAM factories, Toshiba did not, an omission that could have been interpreted as evidence of its withdrawal from that market. Toshiba did, however, announce huge expenditures for ultralarge-scale inte-

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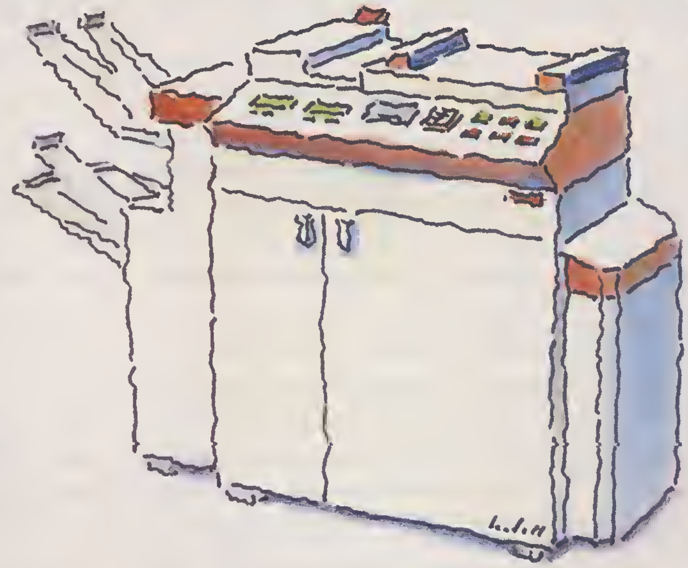
gration development. From this disclosure, an astute observer might have been able to infer the probable end product of that development.



Norm Bendell

Changes in organizational structure also supply clues for competitive intelligence—and these changes are often not confidential. In 1983 Toshiba introduced a three-group system composed of an engineering group for the 256K product, a semiconductor R&D group for the next-generation product, and a basic research center for future products. Numerous researchers and engineers specializing in DRAM technologies were transferred from one group to the next as the DRAM generation changed from 64K to 256K. This rotation maximized manufacturing yields, since the engineers in the factory had worked with the technology from its beginnings.

Setting up this three-group system required the hiring of some 1200 extra engineers, and an analysis of financial statements for 1983–85 showed a 250 billion yen investment in semiconductor development. The conclusion obviously was that Toshiba had made a huge bet—one that made little sense unless the company intended to regain a sizable market share.

At Hitachi, in contrast, large numbers of researchers and engineers in the corporate research center never did transfer to the factory. This structure might hint that the company was more interested in developing innovative technology than in high yields. During this period, NEC moved to strengthen its design center, intending to become a leader in a number of segments of the IC business, including DRAMs. This effort implied a policy of giving first priority to meeting customer needs.

Both these strategies revealed a neglect of the threat from low-cost mass producers and ignorance of Toshiba's aggressive attack on high-yield manufacturing. The result was that Toshiba could easily train workers to operate its factory "by the book," while its competitors needed "craftsmen" engineers for constant troubleshooting.

VIDEOTAPE VICTORY. The case of the Japanese takeover of the videotape manufacturing business is a prime example of the successful application of competitive intelligence. In the late '70s and early '80s, 3M Corp.'s Scotch brand of videotape was widely considered to be the standard of quality. People worldwide were extremely loyal to the brand—many would truly have fought rather than switch.

But today the videotape market is dominated by a number of Japanese companies, including TDK, Sony, Fuji Film, and Hitachi Maxell; 3M lost the game in spite of its head start and strong technology because it did not examine the industry trends nearly as carefully as the Japanese.

To accurately forecast videotape technology trends, the Japanese manufacturers were quite aggressive in their information-gathering. First, they determined that the trend was toward much longer recording times on a single tape cassette. They reached this conclusion by analyzing the specifications that videocassette recorder (VCR) manufacturers provided to component suppliers. They also surveyed the status of R&D efforts of the companies that supply magnetic particles for videotape production, and they conducted market research on VCR users that showed that longer recording time would be a key factor in future purchasing decisions. VCR equipment in the pipeline was clearly going to support longer recording.

On the tape side, a longer recording time would require dramatically increased recording density and a much thinner plastic film base. The tape manufacturers knew that the magnetic particles they were developing in their laboratories at that time would support longer recording times. But the manufacturers of the base film were not making fast enough advances in thinness.

So from the sidelines the Japanese videotape makers kept a close watch on the intense competition among base-film producers, including three international megacompanies (ICI, Hoechst, and DuPont) and two smaller Japanese companies (Toray Industries Inc. and Teijin Ltd.). At the time the megacompanies' technology was at a higher level than that of the Japanese companies, and the three were able to fully satisfy the then current base-film demand. Because of other R&D commitments, however, the bigger companies were not willing to devote the resources needed to quickly develop a new grade of film.

Then, in 1980, while observing all these companies keenly, the Japanese videotape makers, acting independently, noticed to their surprise that one of the Japanese film producers had purchased a commercial-size coating machine for videotape. This represented a large investment, and meant either a new entrant in the videotape manufacturing industry or an aggressive research program for the practical development of new generations of videotape film. After careful examination, each videotape maker decided to join a film producer in speedily developing longer recording videotape. As a result, Japan's base-film technology for videotape advanced rapidly. It became thinner and better in quality, through using crystalline-rich technologies that produce a thin and strong film.

In contrast, the film being developed by the megacompanies was amorphous-rich, which is optically transparent and better suited to other applications of polyester film than to videotape, the dramatic opposite of the approach taken by the Japanese.

In the early 1980s, when the new longer-playing videotape was introduced by the Japanese manufacturers, the megacompanies noticed their technology lagged far behind. Thus 3M, which had relied on the megacompanies' base film in its videotape development and had been overconfident about their standards for quality, had been almost blind to this startling change.

As this example shows, in competitive intelligence, close monitoring of all the participants in an industry is necessary. In this case, acting as a watch dog over the activities of the base-film producers was critical.

Fortunately in this case, the film producer who became a partner with the videotape makers was reluctant to participate in the videotape industry. In similar situations, the supplier could turn into a competitor. Generally, there is always a threat from the supplier that must be kept in mind, because the supplied material is sometimes the key to realizing a highly differentiated product.

REVERSE ENGINEERING. In an industry characterized by head-on competition, such as the copier industry, a program of rapid reverse engineering is perhaps the key competitive intelligence activity. This does not mean that me-too product introduction is a compelling success factor. Rather, reverse engineering is used to determine the competition's long-range R&D direction. Considered in light of the overall manufacturing process, the product design will imply what core technologies are held as the competitive edge. In a copier, many technologies are combined, from specialty chemicals for photosensitive materials to sophisticated software used in the copier's operation. If

specialty chemicals are more advanced in the machine, the company is probably looking toward high-resolution printing characteristics in future copiers. If the focus seems to be on advances in software, the company may well be intending to provide a future bridge between an assortment of office machines.

A few years ago, different technology strategies in the copier business could be detected by simply looking inside each copier. Careful reverse engineering was unnecessary. Ricoh Co.'s models were all equipped with a single, similar engine, with many ICs located at the control panel. Minolta Co.'s models were composed of different units, each of which had its own dedicated control IC. The intelligence gained from these observations was that the first company probably saw the man-machine interface as its key technology, while the second thought much more of manufacturability and assembly.

The copier companies also provide a good example of how important the use of information about recruitment activities is in understanding competitors' plans. A capable personnel manager can easily assess competitors' moves in this area since such information is publicly available from recruitment agencies and advertisements in professional journals. For example, one company seemed to hire as many chemical specialists as possible; this probably indicated that the company was moving toward high-resolution printing. Another company was hiring engineers involved in optical storage; this company was expected to introduce a very complex copier that stored documents optically.

CONSUMER ELECTRONICS. The rapid pace of change in the consumer electronics business makes it one of the hardest industries in which to pursue timely competitive intelligence; but companies whose intelligence activities are unable to keep pace can quickly fall behind.

One executive in charge of R&D in the consumer industry arrogantly stated at several conferences that his company was able to introduce a higher-quality me-too product at a lower price than competitors one year after the launch of any new product by a competitor. Since the company had a strong information network among electronic components suppliers, it could quickly gather information on key parts, so this statement seemed reasonable.

However, in the case of Sony Corp.'s Walkman, the competitive product failed to meet the boast because Sony's new model introduction was too speedy and too varied. Sony created many streams of new models: with tuners for AM, FM, short-wave, and TV-sound; with recording options, including stereo and sound-activated; with sound quality features such as noise reduction, direct drive, equalizer, low-sound enhancer, and shrill-sound reduction; and with operational features such as auto reverse, remote control, rechargeable batteries, and liquid-crystal displays.

Sony's model also included compact features like different cassette sizes and smaller headphones; durability options like antishock and waterproof models; and such design options as a full line of colors and a design for small children. When these abundant models of the Walkman were rushed onto the market, competitors were unable to detect Sony's main market stream in spite of their excellence in competitive intelligence.

One leading Japanese company, Tokyo-based Matsushita Graphic Communication Systems Inc., an affiliate of Matushita Electric Industrial Inc., which has a strong technological reputation, did not do enough in the way of competitive intelligence to counter challenges by consumer electronics companies. For a long time, the company held the technological and market lead in the facsimile industry, and it began to behave as if its position were guaranteed.

But today, the fax market is changing from a business-user market to a home-user market, and skills in consumer electronics are becoming important. Consumer electronics companies have in the past few years been introducing lower-priced models with user-friendly designs, so that the market share of Matsushita Graphic has steadily eroded.

If the company had noticed the threats from consumer electronics companies early, it might have been able to maintain a profitable business by tapping into its parent company's resources. Today, an affiliated company, Kyushu Matsushita Electric Co., with outstanding skills in the manufacture of consumer electronics products, has successfully entered the fax industry, but apparently its entry came too late to regain the top market share.

OPEN ADVANTAGE. Being aware of the intelligence activities of other companies, including competitors, need not turn corporations into secretive fortresses. Often, openness is the best policy.

A few years ago, for example, representatives of a small United States–based start-up that was spun off from a hard-disk drive manufacturer traveled around Japan, looking for a partner to act as exclusive original-equipment manufacturer of an ultrasmall hard disk. From the U.S. company's perspective, it was often difficult to determine the appropriate person to contact in a candidate company unless the company's organizational charts and other information were made available. Thus, the U.S. representatives met only with Japanese suppliers with "open door" policies.

These companies were then fully briefed on the hard disk situation in the United States and given complete descriptions of a handheld PC under development that was to be equipped with a box-sized hard disk smaller than a bar of bath soap.

This information, which came to them without effort or expense, was very valuable because experts in hard-disk engineering are few and mostly located in the United States. Typically, it would take much time and money for Japanese companies to gather their opinions about hard-disk technology trends. Companies without open door policies thus lost the opportunity of obtaining information many of their competitors did obtain.

Selectively releasing important information can also be a competitive strategy. For example, in the advanced liquid-crystal display (LCD) business, Canon Inc., Tokyo, recently announced a futuristic technology developed in its laboratory—ferroelectric LCDs. The goal of the announcement was not to confuse competitors, but to attract industry attention. By showing this advanced feature, the company hoped it would be contacted by a variety of suppliers, and therefore find opportunities for various liaisons for its future business.

As these cases demonstrate, engineers at many Japanese companies have learned that understanding the competitive situation is a part of their jobs. They voluntarily share any information they have collected with others in the company, to improve corporate-wide understanding of the competition, and this exchange of information affects policy decisions. Japanese engineers, as part of the tradition of lifelong employment, are well-trained in these kinds of activities.

In contrast, it seems that Western engineers ignore such activities. Yet competitive intelligence is an essential tool in building a bridge between external activities and internal business decisions. Any company that lacks competitive intelligence will, sooner or later, fall behind.

TO PROBE FURTHER. While these cases were based on the author's experiences in consulting, general information on competitive intelligence gathering is available in *Competitive Intelligence: How to get it; How to use it*, and *Monitoring the Competition: Find out what's really going on over there*, both by Leonard M. Fuld (John Wiley & Sons, 1985 and 1988, respectively); and *The Business Intelligence System: A New Tool for Competitive Advantage*, by Benjamin and Tamar Gilad (Amacom, 1988). An article worth checking out is "An Information Specialist Joins the R&D Team," by Kenneth Walton, John Dismukes, and Jon Browing, *Research Technology Management*, September/October 1989, p. 32. ◆

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The law on reverse engineering

To stay within the bounds of the chip protection act, the chip copier must prove some innovation was added, and must produce a paper trail

When the U.S. Court of Appeals in Washington, DC, last fall upheld a jury's verdict that Advanced Micro Devices Inc. was guilty of illegally copying Brooktree Corp.'s Ramdac chips, it did more than just award US $25 million to the aggrieved Brooktree. At the same time, the judges clearly codified a road map for chip designers intent on reverse-engineering a rival's products.

Reverse engineering—that is, the copying of all or part of a chip for the purpose of analyzing its layout—is legal. That was made clear by the Semiconductor Chip Protection Act of 1984, a Federal law enacted to protect layout designs of ICs. But the law also states that simply copying a design is illegal.

What was unclear in this case concerning the two California companies, however, was just where mere copying ends and reverse engineering begins, and how to prove the difference. The problem was to distinguish reverse engineering, which Congress sought to encourage, from chip piracy, which Congress sought to discourage.

The jury trial began in November 1988 in Federal District Court in San Diego, CA, when Brooktree, in San Diego, alleged that Advanced Micro Devices (AMD), in Sunnyvale, had copied its designs for Ramdacs, infringing three patents in the process. AMD's defense was that the memory-and-converter (or color video) chips were reverse-engineered, not copied. But the jury found otherwise.

TWO-LEGGED DEFENSE. The decision affirms that a reverse-engineering defense must stand on two legs. First, the new product must include some degree of innovation—what the law calls "an original mask work," where the mask is the series of related images that represent the pattern of the chip's layers. In other words, a legitimately reverse-engineered chip is one that is not substantially identical to the original chip.

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Second, as was pounded home by witnesses who testified to Congress before it passed the 1984 law, a substantial paper trail of how the product was designed, as well as a record that considerable time was invested in the work, must be evident. This could include logic and circuit diagrams, trial layouts, and computer simulations.

In fact, industry representatives told Congress then that only reverse engineering, and not chip piracy, generates such a trail. One representative from Intel Corp. even agreed at the time that "[i]t is not the extent of the change, but the extent to which the work can be documented..." that legitimates a reverse-engineered chip.

It was the semiconductor industry itself, beset by chip pirates who would photographically copy a manufacturer's chip and then enter the market with it, that importuned Congress to pass the law. The industry considered a law necessary because chip layout designs, for various reasons, cannot be protected under the more traditional forms of intellectual property protection, such as patents and copyrights.

Kazu

Patents are generally not able to protect the designs because chips lack the novelty and nonobviousness required. Although many circuit designs do fall within the boundaries of that definition, few layouts of those circuits rise to the required level.

Likewise, a copyright is unattainable because it extends to articles that are merely ornamental, not to those that are inherently useful or utilitarian. Since chip layouts are used only to manufacture ICs, they are purely utilitarian. All this set the stage for the suit, *Brooktree v. AMD*, covering two of Brooktree's Ramdacs, the Bt451 and the Bt458. Each chip combines functions of a static random-access memory (SRAM) and a digital-to-analog converter to produce the colors in computer video displays. Both of the chips have been highly successful commercially.

KEY TESTIMONY. In AMD's attempt to establish demonstrable innovation, key testimony centered on a critical element of Brooktree's design: a 10-transistor SRAM cell repeated more than 6000 times in the chip's layout. AMD admitted studying the Ramdac design, including the SRAM cell.

One AMD designer testified that he first tried to design a SRAM cell using six transistors. But, after opening several Bt451 chips, photographing them, and enlarging the photos, he prepared a "reverse-engineering report" in which he concluded, incorrectly, that the Brooktree SRAM cell contained eight transistors. His attempt to design a SRAM cell with eight transistors, though, was unsuccessful, so he tried 10 transistors, as used by the Brooktree chip. He then was able to solve the problem very quickly, in about a week.

An important question was what inspired the AMD designer to try the 10-transistor design. He denied that he learned of it from the Brooktree chip, claiming instead that it was suggested to him by a job candidate he interviewed. But that person had since died and no other documentation of the designer's work had been kept; so AMD was unable to corroborate that the designer's own work, not the Brooktree chip, was the source of its design.

Once the AMD designer completed the design of the SRAM cell, he prepared a layout of the circuit elements in the cell. He testified that, in preparing that layout, he never changed the location of the 10 transistors. In contrast, the designer of the Brooktree cell testified that he changed the positions of the transistors as many as six times before settling on the final design.

Many other striking similarities existed between the two designs. Among them, testimony showed, was the identical positioning of the transistors in the AMD cell with those in the Brooktree cell. Minor differences resulted from variations in the fabrication technologies used by each company and in layout design rules defining the widths and spacing of the elements.

Another similarity was that the metal lines crossing the AMD SRAM cell were in the same sequence as those in the Brooktree cell, and though the AMD cell contained one extra metal line, it was un-

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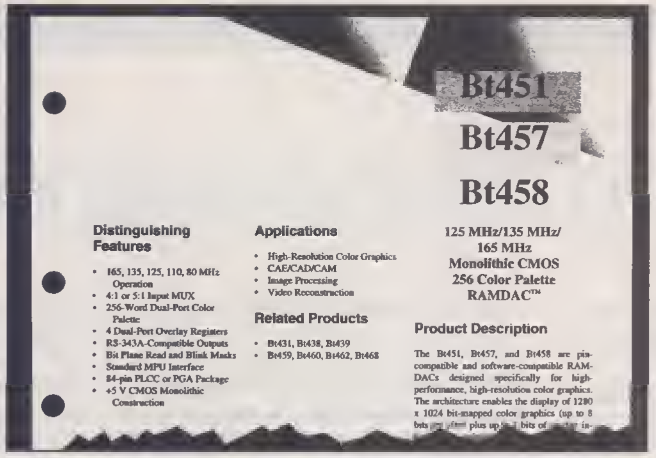

The U.S. Court of Appeals agreed that Brooktree's Bt451 and Bt458 Ramdac chips had been copied by Advanced Micro Devices.

related to the SRAM cell. The AMD designer admitted he originally included in his layout a 45-degree-angle portion of metal that also appeared in the Brooktree layout, but he had later removed the angled position because it was not compatible with AMD's manufacturing process. The Brooktree designer said he included the angled portion to produce a more compact layout.

The differences between the two layouts were insignificant. The AMD cell and the AMD chip were both smaller and faster than Brooktree's, but this was due to AMD's use of its 1.6-µm technology, compared with Brooktree's older 2.0-µm process. Also, the AMD chip used different layouts and interconnections between the SRAM cells and other portions of the chip.

Despite the differences, the jury concluded that AMD's cell was copied from Brooktree's, and was not the product of reverse engineering. The case, however, provides little precedent regarding the first important element of a reverse-engineered design—that it be substantially different from its alleged model—because of the extreme similarities of the SRAM cells in the two designs.

As for the second leg of the reverse-engineering defense, AMD presented substantial documentation to show it had attempted to reverse-engineer Brooktree's design. In fact, the judge instructed the jury to place "great weight" on that material. Nonetheless, the jury found AMD's defense unacceptable.

LESSONS TO LEARN. What are the lessons from this trial for future reverse-engineering efforts? For one thing, manufacturers should carefully document all steps of the project. Such documentation should include all photographs taken of the original chip and trial layouts for the new chip. Those layouts should be retained in hard copy, on magnetic tape, or in a computer database.

AMD could not prove that its designer conceived the SRAM cell in its Ramdac chip, in part because no source was cited to support the designer's inspiration except the designer's own testimony. Separate corroborating evidence might have changed the outcome of the case.

Most importantly, the thought processes of the engineers who decipher the original chip should be retained. Only by showing the design choices, and the reasons for those choices, can it be demonstrated that the reverse-engineered chip is an "original mask work" as required by the statute. Clear documentation that the engineers hit on a design that was based upon, but independent of, their investigation of the original chip will refute a charge of piracy.

Engineering notebooks are the perfect means for recording engineers' design efforts, and they should be used during reverse engineering. Many engineers already use notebooks to document inventions, and many companies require them for equations, sketches, and commentary about work in progress. Each page should be signed and dated by the engineer and witnessed by at least one co-worker. It cannot be emphasized enough that engineers making the changes from the old to the new chips must allow themselves enough time to document their work.

The Brooktree case also illustrates several examples of changes from old to new chips that were insufficient to show innovation—for example, changes made to accommodate different fabrication rules. One thing that could help is to at least rearrange the devices that form the circuit, even if this yields a less efficient design. Since the law protects only the geometric interrelation of the devices, AMD might have escaped liability if it had used Brooktree's 10-transistor SRAM cell circuit but had rearranged the transistors.

As it turned out, according to an announcement in May, the total amount that changed hands between Brooktree and AMD was $28 million—the $25 million penalty, plus costs and interest. The two companies also said that they had settled their patent and mask-making differences.

FORMS OF PROTECTION. The outcome of the *Brooktree* case, to date the only one tried under the 1984 chip protection act, contains lessons for other chip manufacturers seeking to protect their intellectual property rights. The act permits a competitor to photograph and analyze the mask work, removing layers from a chip to determine the geometries of the layers below. From the patterns, the competitor can determine the nature of the circuit elements and their interconnections, and use the results of that study in a different, competing mask work.

It behooves chip manufacturers then to design their products with the reverse engineer in mind, making their layouts difficult to decipher. In their manufacture of the chips, too, they should include steps that no other manufacturer has access to, so that reverse-engineered layouts will be useless.

In fact, the layout itself should be designed to detect reverse engineering. Shapes or patterns that perform no function may be added to trap a chip pirate who is merely copying shapes without understanding their function.

Where adding shapes is not practical, inactive circuit elements may be included. Often, circuit designers may be uncertain about the right value for a circuit component, such as a resistor's resistance or a field-effect transistor's dimensions. They may decide to allow themselves the opportunity to "tweak" the circuit after manufacture to improve performance without changing all of its mask layers.

Thus, they could include extra devices that might later be connected to the circuit by changing a single layer, such as the metal interconnect layer. The presence of these devices in a competitor's reverse-engineered chip is strong evidence that the company did not expend the effort necessary to understand the chip's function.

Both these strategies—the use of additional inactive shapes and the use of additional unconnected devices—may make the chip somewhat less manufacturable. Still, the benefits of being able to detect chip piracy under the act could outweigh that disadvantage.

Other techniques unrelated to chip layout may also protect a chip design. For example, a unique manufacturing process may be used to make a chip layout undecipherable. Classic chip pirates merely photographically reproduce the layout of an IC. But a pirate lacking access to a compatible process will be left with masks for a chip that cannot be manufactured.

Another level of protection is to make the manufacturing process for the chip patentable. And the circuits that form the chip may also be patentable. In the *Brooktree* case, the circuit for the SRAM cell circuit was patented, and the patent was found to be infringed.

Finally, many chips include a software component in their design. Since microcode is software embedded in the chip and is used to control the functioning of the chip's hardware, it may be protected by copyright. Any reverse engineer who copies the circuitry containing the microcode infringes the copyright on the microcode. ◆

ABOUT THE AUTHOR. John G. Rauch is an attorney with the law firm of Foley & Lardner, Chicago. He previously worked for five years as an IC design engineer. This article reflects only the author's views, which should not be attributed to Foley & Lardner or any of its former or present clients.

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(Continued from p. 12)

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Video Engineering. *Inglis, Andrew F.*, McGraw-Hill, New York, 1993, 338 pp., $49.95.

Radar: Principles, Technology, Applications. *Edde, Byron*, Prentice Hall, Englewood Cliffs, NJ, 1993, 717 pp., $55.

Multiresolution Signal Decomposition: Transforms, Subbands, Wavelets. *Akansu, Ali N.*, and *Haddad, Richard A.*, Academic Press, San Diego, CA, 1992, 376 pp., $59.95.

REXX: Advanced Techniques for Programmers. *Kiesel, Peter C.*, McGraw-Hill, New York, 1993, 239 pp., $39.95.

The People Dimension: Managing the Transition to World-Class Manufacturing. *Recardo, Ronald J.*, and *Peluso, Luigi A.*, Quality Resources/The Kraus Organization, New York, 1992, 203 pp., $29.95.

From Machine Shop to Industrial Laboratory: Telegraphy and the Changing Context of American Invention, 1830–1920. *Israel, Paul*, Johns Hopkins University Press, Baltimore, MD, 1992, 251 pp., $38.50.

Tom Swan's C++ Primer. *Swan, Tom*, SAMS/Prentice Hall, Carmel, IN, 1992, 740 pp., $34.95.

Guide to Writing DCE Applications. *Shirley, John*, O'Reilly & Associates, Sebastopol, CA, 1992, 282 pp., $29.95.

The Winn L. Rosch Hardware Bible, 2nd edition. *Rosch, Winn L.*, Brady/Prentice Hall, New York, 1992, 1060 pp., $34.95.

Understanding DCE. *Rosenberry, Ward, et al.*, O'Reilly & Associates, Sebastopol, CA, 1992, 266 pp., $24.95.

Computer Analysis of Structural Frameworks, 2nd edition. *Balfour, James A.D.*, Oxford University Press, New York, 1992, 490 pp., $65.

The Data Handbook: A Guide to Understanding the Organization and Visualization of Technical Data. *Fortner, Brand*, Spyglass, Champaign, IL, 1992, 229 pp., $39.95.

Communications and Networking for the IBM PC and Compatibles, 4th edition. *Jordan, Larry*, and *Churchill, Bruce*, Brady/Prentice Hall, Carmel, IN, 1992, 693 pp., $29.95.

Advanced Assembly Language. *Wyatt, Allen L., Sr.*, Que, Carmel, IN, 1992, 705 pp., $39.95.

A Manager's Guide to Software Engineering. *Pressman, Roger S.*, McGraw-Hill, New York, 1993, 528 pp., $44.95.

Moving From C To C++. *Perry, Greg*, SAMS/Prentice Hall, Carmel, IN, 1992, 404 pp., $29.95.

MH & xmh: E-mail for Users & Programmers. *Peek, Jerry D.*, O'Reilly & Associates, Sebastopol, CA, 1992, 728 pp., $29.95.

The Microsoft Visual Basic for MS-DOS Workshop. *Craig, John Clark*, Microsoft Press, Redmond, WA, 1993, 464 pp., $39.95.

FDDI: An Introduction to Fiber Distributed Data Interface. *Michael, Wendy H., et al.*, Digital Press, Burlington, MA, 1993, 224 pp., $17.95.

Nanosystems Molecular Machinery, Manufacturing, and Computation. *Drexler, K. Eric*, John Wiley & Sons, New York,

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Physical Acoustics: Ultrasonics of High-T_c and Other Unconventional Superconductors, Vol. XX. Ed. *Levy, Moises*, Academic Press, San Diego, CA, 1992, 465 pp., $99.

Windows for Workgroups. *Jamsa, Kris*, Microsoft Press, Redmond, WA, 1993, 250 pp., $12.95.

Fundamental Thermodynamics at the Micro Level. *Johnson, John Frank*, Royal Publishing, Roanoke, VA, 1992, 48 pp., $50.

Object Linking and Embedding Programmer's Reference. *Microsoft Corp.*, Microsoft Press, Redmond, WA, 1992, 448 pp., $27.95.

Control and Dynamic Systems: Advances in Theory and Applications, Vol. 52. Ed. *Leondes, C.T.*, Academic Press, San Diego, CA, 1992, 550 pp., $79.95.

Predictive Control: A Unified Approach. *Soeterboek, Ronald*, Prentice Hall, Englewood Cliffs, NJ, 1992, 352 pp., $60.

Artificial Intelligence in Engineering Design, Vol. 1. Eds. *Tong, Christopher*, and *Sriram, Duvvuru*, Academic Press, San Diego, CA, 1992, 473 pp., $39.95.

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Technology and the Wealth of Nations. Eds. *Rosenberg, Nathan, et al.*, Stanford University Press, Stanford, CA, 1992, 443 pp., $49.50 (cloth), $16.95 (paperback).

Effective Management of Local Area Networks: Functions, Instruments, and People. *Terplan, Kornel*, McGraw-Hill, New York, 1992, 376 pp., $39.95.

Polymers for Electronic and Photonic Applications. Ed. *Wong, C.P.*, Academic Press, San Diego, CA, 1993, 661 pp., $93.50.

X Window System Administrator's Guide, for X Version 11. *Mui, Linda*, and *Pearce, Eric*, O'Reilly & Associates, Sebastopol, CA, 1992, 372 pp., $29.95.

The OSI Dictionary of Acronyms & Related Abbreviations. Eds. *Brown, Wendy E.*, and *Simpson, Colin McLeod*, McGraw-Hill, New York, 1993, 193 pp., $29.95 (hardcover), $19.95 (paperback).

LEX & YACC. *Levine, John R., et al.*, O'Reilly & Associates, Sebastopol, CA, 1992, 400 pp., $29.95.

Data Fusion in Robotics and Machine Intelligence. Eds. *Abidi, Mongi A.*, and *Gonzalez, Rafael C.*, Academic Press, San Diego, CA, 1992, 546 pp., $59.95.

Paradigm Shift: The New Promise of Information Technology. *Tapscott, Don*, and *Caston, Art*, McGraw-Hill, New York, 1993, 337 pp., $24.95.

Mathematical Modeling of Melting and Freezing Processes. *Alexiades, Vasilios*, and *Solomon, Alan D.*, Hemisphere Pub-

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lishing, Bristol, PA, 1993, 323 pp., $49.50.

Paradox 4.0 Developers's Guide. *Greaves, Dana,* and *Lindsay, Jennifer,* Que/Prentice Hall, Carmel, IN, 1992, 978 pp., $44.95.

Theory of CMOS Digital Circuits and Circuit Failures. *Shoji, M.,* Princeton University Press, Princeton, NJ, 1992, 570 pp., $49.50.

FractalVision: Put Fractals to Work for You. *Oliver, Dick,* SAMS/Prentice Hall, Carmel, IN, 1992, 485 pp., $39.95.

Downsizing to NetWare. *Day, Michael, et al.,* New Riders, Carmel, IN, 1992, 710 pp., $39.95.

Microsoft Money 2.0. *Nelson, Stephen L.,* Microsoft Press, Redmond, WA, 1992, 304 pp., $19.95.

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Electrical Resistivity Handbook. *Dyos, G.T.,* and *Farrell, T.,* IEE/Peter Peregrinus, Piscataway, NJ, 1992, 735 pp., $175.

ISO 9001: The Standard Companion. *Beaumont, Leland R.,* ISO Easy, Middletown, NJ, 1992, 17 pp., (1–49) $3.95; (50–249) $3.50; (250–999) $3.00; (1000+) $2.75.

The Foundations of Technology Transfer in American Industry. *Olken, Hyman,* Olken Publications, Livermore, CA, 1992, 90 pp., $16 (order prepaid), $17 (invoiced price).

Enterprise Integration Modeling: Proceedings of the First International Conference. Ed. *Petrie, Charles J., Jr.,* MIT Press, Cambridge, MA, 1992, 563 pp., $45.

Opto-Mechanical Systems Design, 2nd edition. *Yoder, Paul R., Jr.,* Marcel Dekker, New York, 1993, 688 pp., $110.

The Digital Technical Documentation Handbook. *Schultz, Susan I.,* Digital Press, Burlington, MA, 1993, 320 pp., $24.95.

Secrets of the Visual Basic for Windows Masters. *Entsminger, Gary,* SAMS/Prentice Hall, Carmel, IN, 1992, 600 pp., $39.95.

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The Digital Style Guide. *Darrow, Jennifer J.,* Digital Press, Burlington, MA, 1993, 350 pp., $24.95.

Peter Norton's PC Problem Solver, 2nd edition. *Norton, Peter,* and *Jourdain, Robert,* Brady Books, New York, 1992, 696 pp., $29.95.

Theory of CMOS Digital Circuits and Circuit Failures. *Shoji, Masakazu,* Princeton University Press, Princeton, NJ, 1992, 570 pp., $49.50.

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Electronic Phase Transitions, Vol. 32. Eds. *Hanke, N.,* and *Kopaev, V.,* Elsevier Science Publishers, New York, 1992, 320 pp., $179.50, $155 (subscription price).

EEs' tools & toys

Probing fine-pitch IC packages

The tighter the leads on integrated-circuit packages, the harder it becomes to probe them. Custom solutions exist, but they are costly, and take time to implement—an important time-to-market consideration.

Enter Tektronix Inc. and its P656X series of oscilloscope probes for surface-mounted devices (SMDs). The low-mass units have bodies less than 4 cm long and a mere 2.5 mm wide. They are passive units with 0.635-mm sockets into which a variety of tips and adapters may be inserted.

One particularly useful accessory is Tektronix' SureFoot probe tip guide [photo]. Its miniature plastic tines align with the SMD's leads before the probe tip itself makes contact with one of them. The tines fit between the IC leads, preventing the probe tip from shorting adjacent package leads.

The probe family consists of three members. The P6561AS, which works with the TAS400 and TDS300 scope families, has a bandwidth of 200 MHz and a price tag of US $350 for a two-probe set. The P6562AS has a bandwidth of 350 MHz and works with the 2400, 11 000, and TDS400 series. It is priced at $740 for four probes.

The top-of-the-line probe set is the P6563AS. It has a bandwidth of 500 MHz and sells for $790 for a set of four. It is intended for use with the TDS500/600 family of oscilloscopes.

Each probe comes with an assortment of adapters and tips, including two SureFoot guides, a ground lead, and a screwdriver. *Contact: Tektronix Inc., Test and Measurement Group, Box 1520, Pittsfield, MA 01202; 800-426-2200; or* **circle 115.**

The insulating plastic tines on the SureFoot probe tip guide enable a user to probe a fine-pitch IC package manually without fear of shorting its leads.

COMPUTER-AIDED DESIGN

Human interfaces in a hurry

The importance of good human interfaces on all sorts of equipment from automobiles to videocassette recorders has been exceeded only by the difficulty of designing them. To model an interface on a computer system, designers typically had the choice of writing their own graphics code—a lengthy and laborious business—or using a graphics tool kit, which limited them to a set of standard interface components.

In this Altia design of an automobile dashboard, the switches and buttons work, the steering wheel turns, and the meters display current data. The instrument panel may be connected to code or simulation software and hardware to create a complete simulation system.

Now, thanks to Altia Design 1.2, designers can create completely custom interfaces without writing a line of code. The software package includes an absolute coordinate and dimensioning system that permits the design of interfaces to precise physical specifications. It also supports the importing of color bit-maps from other design systems or scanners, which can speed the completion of an interface.

Like the original Altia Design package, version 1.2 includes a suite of interactive animation features and a robust graphical editor. It includes a run time version for software integration into the final product under design.

To allow product developers to travel to their customers' sites and demonstrate their prototypes, Altia Design 1.2 supports the Tadpole SparcBook, a portable Sparc-compatible workstation.

The complete design system is priced at $7900 for a single license; discounts are available for multi-license purchases. *Contact: Altia Inc., 5030 Corporate Plaza Dr., Suite 200, Colorado Springs, CO 80919-9901; 719-598-4299; fax, 719-598-4392; French readers only should phone Antycip at (33+1) 3961 1414; or* **circle 104.**

Modeling RF transistors

Electronic design automation (EDA) is a wonderful thing, capable as it is of reducing design time while improving both yield and product reliability. The fly in the EDA ointment is that it depends on sophisticated transistor models, which are not always available for the latest high-frequency devices.

To overcome that problem, at least for users of its popular Libra, J-Omega, and Touchstone circuit simulators, EEsof Inc. has announced a transistor-modeling service for medium- and high-power silicon and gallium arsenide RF transistors.

The medium-power modeling service is offered for transistors operating in Class A/AB with power dissipation up to 3 W. It produces models based on a series of dc and small-signal ac measurements made upon five devices submitted by the customer.

In addition to a parameter file for a large-signal-transistor model, deliverables include plots of measured vs. simulated dc I-V curves plus plots of measured and simulated S-parameters vs. frequency at a dc bias value specified by the customer.

At present, the high-power service relies on data supplied by transistor manufacturers, although EEsof plans to offer a measurement-based service later this year. Deliverables include a large-signal parameter file and plots of output vs. input power, impedance vs. frequency, and such other information as power gain and efficiency.

Pricing for the transistor models starts at $3000. They typically take two weeks to develop. *Contact: EEsof Inc., 5601 Lindero Canyon Rd., Westlake Village, CA 91362; 800-343-3763; or* **circle 105.**

GENERAL INTEREST

Political software

President Clinton, his wife, daughter, and cat together receive about 700 000 letters a

month. Other Washington insiders receive much less mail. Lest those lesser movers and shakers feel left out of the political process, Political Systems Inc. has developed a software package for personal computers that should get them all the printed matter they can handle... and then some.

Called Political Action, the package works as an electronic lobbyist. It automatically generates letters, telegrams, mailgrams, and faxes at a rate of up to 10 a minute and sends them to a user-specified selection of representatives, senators, Supreme Court justices, foreign leaders, governors, and members of the press.

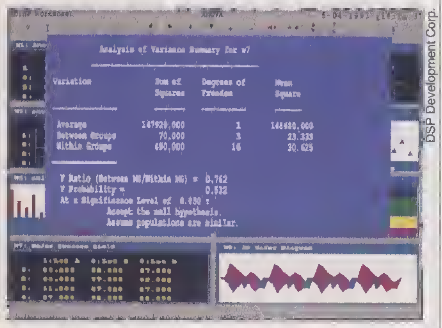
The user of the software writes a message, selects a target group, and hits the SEND button. The program then looks up the addresses of the target group in its built-in database and automatically dispatches the messages. Typically, the missives are sent via ATT Easylink, GEnie, Compuserve, or MCI Mail, but they may also be sent using a fax modem or simply printed and mailed.

Political Action version 1.0 is priced at $195. *Contact: Political Systems, 200 Seventh Ave., Suite 200, Santa Cruz, CA 95062; 408-462-2222; fax, 408-462-9338; or* **circle 106.**

SOFTWARE

Friendly statistics

Engineers and scientists with a need to perform sophisticated statistical analyses and a preference for menu-driven graphical user interfaces will appreciate DADiSP/Stats, an add-on module for DADiSP, the popular graphical analysis package.



DSP Development Corp.

DADiSP/Stats, an add-on package for DADiSP, uses the familiar menu-driven DADiSP environment for performing a wide variety of statistical operations.

With DADiSP/Stats, users can perform 15 different statistical operations. Among them are T tests, analyses of variance, multiple regression, chi square tests, and statistical and quality-control graphs.

Because the new package was developed using DADiSP's Menu Builder Toolkit and macro extension language, its menu and macro files can be read (and modified, if desired). Users can thus verify the statistical algorithms and change the individual functions and menus to adapt them to their particular needs.

Each DADiSP/Stats menu option automatically generates a presentation-quality test report or graph that may be incorporated into a document or printed by itself.

DADiSP/Stats is sold for $495 for PCs and $795 for workstations. *Contact: DSP Development Corp., One Kendall Square, Cambridge, MA 02139; 617-577-1133; fax, 617-577-8211; or* **circle 107.**

Nice neural nets

Descriptions of what others have done by employing neural networks are enticing, but coming to grips with the complex concepts and software involved is daunting.

Propagator, a software package for Sun workstations and the PC and Macintosh, should end trepidation and accelerate application. The software, with its point-and-click interface, simplifies the training of neural networks, while the manual guides the novice through the fundamentals. Even experienced neural network engineers may find the software speeds their work.

To simplify the software, its originators have concentrated on supporting variations of only the most common learning algorithm: back propagation. Three main dialog boxes control the setup of neural network variables, such as learning rate, momentum, number of layers, transfer function, noise, initial weighting, and stopping criteria. Users can employ a validation set to see when to stop training because the network is starting to "overlearn," while three types of training graphs—error vs. cycle, error vs. output unit, and output unit vs. error—let users see how well network training is progressing.

The Sun version of Propagator, which runs under Solaris 1.X and 2.X, is priced at $499 and is available now, complete with free technical support and a money-back guarantee. The PC/Windows and Macintosh/OS 7.X versions should appear in the next quarter and sell for $199. *Contact: ARD Corp., 9151 Rumsey Rd., Columbia, MD 20145; 410-997-5600; or* **circle 108.**

DIGITAL SIGNAL PROCESSING

Multiprocessing made easier

An inescapable drawback of working with new technologies is the lack of a supporting infrastructure. The pioneer has not only to clear a lot of ground, but frequently also to make the necessary tools. To ease that situation for designers on the frontier of digital signal processing (DSP), 3L Ltd. of Edinburgh, Scotland, has introduced a parallel DSP library for developers of multiprocessing systems of DSPs.

To be specific, the library is optimized for 3L's Parallel C compiler for the Texas Instruments TMS320C40 DSP, which was designed by the Texas company for parallel DSP applications. For single-processor applications, the library is also compatible with TI's own C compiler.

Among the library's algorithms are routines for filtering, convolution, and general-purpose vector and matrix processing. These include Hanning, Hamming, Blackman, Blackman-Harris, and rectangular windowing functions; linear and cyclic convolution and correlation; finite-impulse-response and infinite-impulse-response filter designs; and a multitude of spectral analysis functions. The library is priced at UK £965. *Contact: 3L Ltd., 86/92 Causewayside, Edinburgh EH9 1PY, Scotland; (44+31) 662 4333; fax, (44+31) 662 4556; e-mail, threeL@threeL.co.uk; or* **circle 109.**

INSTRUMENTATION

Fast digital scope

It is axiomatic that measuring instruments must be faster and more accurate than the equipment they test. Thus, as computers and communications gear keep getting faster, instruments like digital oscilloscopes must get faster still. Fortunately, the world's instrument makers have proven equal to the challenge.

Witness, for example, LeCroy's latest oscilloscope, the Model 9360. It is a two-channel unit with a bandwidth of 600 MHz and a sampling rate of 5 gigasamples per second on each of its channels.

Thanks to its sampling rate of 5 gigasamples per second on each of its two independent channels, the LeCroy Model 9360 can find sub-nanosecond glitches in high-speed circuitry.

The single-shot scope offers memory lengths of 500–20 000 points, depending on its operating mode. It has two sets of inputs: a 50-Ω pair that provides the full 600-MHz of bandwidth, but is rated at 1-V maximum; and a pair that spans only 300 MHz, but can handle a peak of 250 V.

The 9360 may be used with LeCroy's AP020 1-GHz active probes, which have an

input impedance of 1 MΩ shunted by 2 pF. Other options include an internal printer, a 3.5-inch floppy disk drive, a memory card and reader, and software for performing waveform math as well as fast Fourier transforms.

The scope itself is priced at $12 490, and the active probe costs an additional $990. The printer goes for $890; the disk drive for $590; the memory card and reader for $500; and the software packages for $1250 each. *Contact: LeCroy Corp., 700 Chestnut Ridge Rd., Chestnut Ridge, NY 10977-6499; 914-578-6020; fax, 914-578-5985; or* **circle 110.**

Cellular safety

Given the public's concern about the potential hazards of RF emissions from cellular telephones and communications centers, manufacturers and operators of cellular equipment will probably find it wise to measure the radiation associated with their products and facilities—to fix it if it is too high, or to brag about it if it is low. To help them with those measurements, General Microwave Corp. has developed its Raham family of radiation hazard meters.

The family includes a wide variety of meters, spanning various frequency ranges, but all including the 800–900-MHz cellular band. The top-of-the-line unit works from 200 kHz to 40 GHz and has four decade scales: 0.02, 0.2, 2.0, and 20.0 mW/cm^2, full scale. It is designated the Model 40, and sells for $3800.

At the low end of the line is the badge-type Model 65, which clips onto a belt or pocket and sounds an alarm when the power density exceeds either 1 mW/cm^2 (Model 65-1) or 5 mW/cm^2 (Model 65-5). The Model 65 is priced at $600.

Another unit, the badge-type Model 60, offers two measurement modes: instantaneous and average exposure level. The latter mode averages exposure over a 6-minute interval. The Model 60 has a liquid-crystal display as well as an audible alarm. It sells for $700.

All three models, plus four others, are available from stock to 30 days. *Contact: General Microwave Corp., 5500 New Horizons Blvd., Amityville, NY 11701; 516-226-8900; or* **circle 111.**

EDUCATION

Safety and health standards

Here's a provocative trivia question: how many standards relating to safety and health have been approved and published by the American National Standards Institute (ANSI)? The answer is 1230, and all of them are listed in ANSI's new *1993 Safety & Health Catalog*, which is available free of charge in single quantities.

The catalog lists standards by subject and ANSI designation numbers and titles. It also has an index.

Speaking of standards, World Standards Day will be celebrated on Oct. 14, and a paper competition will be held as part of the celebration. Jointly sponsored by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) as well as ANSI, the competition has as its theme, "Standards: A Strategic Investment."

The deadline for submitting papers illustrating how critical standardization is to competitiveness is Aug. 15. The author of the winning paper will receive a plaque and an award of $2500. *Contact: American National Standards Institute, 11 West 42nd St., New York, NY 10036. For information about the paper competition, phone the Standards Engineering Society at 513-223-2410. To request a copy of the* Safety & Health Catalog, *phone ANSI at 212-642-4900; or* **circle 114.**

COORDINATOR: Michael J. Riezenman
CONSULTANT: Paul A.T. Wolfgang, Boeing Defense & Space Group

IEEE Technical Field Awards

The two dozen recipients include three who worked on the Sony Walkman and the three developers of Texas Instruments' Speak & Spell

The IEEE's Board of Directors named 24 winners of the Institute's 1993 Technical Field Awards, acknowledging the outstanding contributions of electrical and electronics engineers to various fields. The awards and their recipients are:

• The Cledo Brunetti Award to **Mitsuru Ida**, **Yoshiyuki Kamon**, and **Takafumi Nambu** (nonmembers) for the development of the Walkman, at the time a totally new concept in miniature consumer electronics. All three award recipients are employed at Sony Corp., Tokyo.

Ida, now a chief engineer, joined Sony upon graduation from college in 1965. Assigned to a mechanical engineering group in the tape recorder division, he worked until 1977 on the TCM-100, at that time the world's smallest and lightest tape recorder. Between 1977 and 1989, Ida was engaged in developing the Walkman and its various models. He played a key role in engineering the smallest Walkman—the WM-1—and the first Walkman to operate on 1.5 V, the WM-10.

Kamon, senior general manager in the General Audio division, also joined Sony upon his graduation, in 1968. He did research on battery fuel for electric vehicles at Sony's Central Research Center until 1974. For the next three years, he developed speaker vibration and magnet materials, and compact speaker units, and then was responsible for the research and design of the compact, lightweight headphones that are essential to the Walkman. He is currently responsible for product development of compact active speakers and microphones.

Since joining Sony in 1970, Nambu has been primarily engaged in projects related to analog tape. From 1971 to 1981, he worked on the technology for manufacturing open-reel decks and on the development of cassette tape recorders and radio cassette-recorders. His Nambu system pioneered the speaker-driving power amplifier for the first cassette tape recorders. His accomplishments in the Walkman engineering group include the 1.5-V operation that has become the standard for Sony's models, and the use of reflow soldering in mass production.

• The Control Systems Award to **Moshe Zakai** (LF) "for contributions to nonlinear stochastic analysis, and its applications to control systems." A native of Poland, Zakai did research for the Israeli Ministry of Defence's Scientific Department and lectured at the University of California at Berkeley. In 1965, he joined the faculty of the Technion—Israel Institute of Technology—where he served as dean of the faculty of engineering from 1970 to 1973 and as vice president for academic affairs from 1976 to 1978. He is currently Technion Distinguished Professor.

Zakai's work has focused mainly on applications of stochastic systems to problems in communications and control. The solution to the modeling problem of stochastic differential equations that he derived in the form of a linear equation was of fundamental importance in the implementation of nonlinear filters and optimal stochastic control. His current research interests include multiparameter processes and the stochastic calculus of nonlinear functions of white noise.

• The Herman Halperin Electric Transmission and Distribution Award to **Mat Darveniza** (F) "for contributions to the lightning protection of power equipment, including both engineering analysis and protective equipment design."

Darveniza has taught since 1959 at the University of Queensland, Australia, in the department of electrical engineering, which he chaired from 1983 to 1987. His work has been notable for integrating laboratory experiments, computer-aided simulation and analysis, and field studies of lightning protection techniques. He is the author of over 200 scientific and engineering publications and the coauthor of *Lightning Injuries: Electrical, Medical and Legal Aspects*.

• The Masaru Ibuka Consumer Electronics Award to **George L. Brantingham** (nonmember), **Paul S. Breedlove** (M), and **Richard H. Wiggins** (M) "for pioneering contributions to consumer electronics products employing synthetic speech for education and entertainment."

These recipients were involved in the development of Texas Instruments (TI) Inc.'s Speak & Spell learning aid for children. The success of Speak & Spell led to increased research in speech processing at TI and to the development of a general-purpose, single-chip digital-signal processor. As a result, millions of commercial products employing successors to TI's original voice output device are now manufactured each year.

Brantingham joined TI in Dallas in 1973, and in 1976 became chief designer and design manager for the integrated circuit portion of the Speak & Spell project. From 1980 to 1984 he created and managed TI's European Speech Laboratory in Nice, France. In 1991 he established the TI Component Design Group in Avezzano, Italy, whose goal is to develop very low-power central processors for battery-powered, handheld products.

Director of technology at CompuAdd Computer Corp., Austin, TX, since 1992, Breedlove was responsible for the concept of Speak & Spell and led TI's development team. Before joining the company in 1972, he worked as a design engineer at IBM, Collins Radio, and Motorola, where he helped conceive the 6800 microprocessor.

Wiggins joined the Central Research Laboratories at TI in 1976, and shortly after developed the speech analysis and synthesis system for Speak & Spell. His innovations in speech synthesis, which permitted the generation of high-quality speech with a single IC chip, reduced the cost of linear predictive coding synthesizers, and led to their application in commercial products. He also developed voice-processing procedures that have increased the vocabularies and improved the speech quality of talking electronic products.

• The Award in International Communication to **Pekka Tarjanne** (nonmember) "for his vision and leadership in restructuring and re-orienting the International Telecommunication Union to the new telecommunications environment."

Tarjanne has been secretary-general of the International Telecommunication Union since 1989, where he has led the development and interconnection of worldwide telecommunication networks. As director-general of Finnish Posts and Telecommunications between 1977 and 1989, he deregulated telecommunications services and transformed the telecommunications sector into a commercial company.

A member of the Finnish parliament from 1970 to 1977, he also served as Minister for Transport and Communications

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from 1972 to 1975.

• The Reynold B. Johnson Information Storage Award to **John Harker** (F) “for leadership in the development of information storage devices, including key contributions to the design of many generations of magnetic disk drives.”

Andy Schenck

Harker joined IBM Corp. in 1952 as a design engineer on the first random-access disk file, the IBM Ramac 350. He was engineering manager for the trillion-bit photodigital mass storage system developed for the Atomic Energy Commission.

In 1970, Harker became product manager for IBM’s disk file product line, leading the successful introduction of Winchester technology in the 3340 and 3350 disk drives. In 1972 he was named director of IBM’s San Jose Development Laboratory. He has been a consultant to IBM since retiring in 1987.

• The Richard Harold Kaufmann Award to **George W. Walsh** (LF) “for the introduction of complex nonfundamental-frequency analytical techniques to practical industrial power system applications.”

Walsh has been at General Electric Co., Schenectady, NY, since graduating from college in 1947. Joining the Industrial Power Systems Engineering Operation in 1955, he participated in all phases of system design and analysis and became a leader in the field. As manager of Electric Power Systems Advance Engineering at GE between 1967 and 1987, Walsh conducted pioneering work in the application of metal-oxide surge arrestors to switchgear, arc furnace systems, and general industrial networks. He is a member of the Power Engineering Society and the Industry Applications Society, of which he was president in 1983.

• The Koji Kobayashi Computers and Communications Award to **Gottfried Ungerboeck** (F) “for contributions to signal processing for data communications, specifically for pioneering trellis-coded modulation.”

In 1967 Ungerboeck joined the IBM Zurich Research Laboratory in Rueschlikon, Switzerland, where he has been in charge of signal-processing activities since 1978. He has pioneered many signal-processing techniques for digital data transmission and storage, notably trellis-coded modulation. He has also investigated problems in digital speech processing, satellite transmission, magnetic recording, signal detection, equalization, and synchronization. He now heads a group dealing with high-speed data transmission over unshielded twisted-pair cables.

• The Morris N. Liebmann Memorial Award to **B. Jayant Baliga** (F) “for pioneering contributions to the development of advanced power semiconductor devices leading to the emergence of smart power technology.”

Between 1974 and 1988, Baliga worked at the GE Research Center, Schenectady, NY, on power semiconductor devices and high-voltage ICs. He pioneered the concept of MOS-bipolar functional integration, which resulted in a new family of discrete power devices. In 1991, he became founding director of the Power Semiconductor Research Center, an international industrial consortium for research and smart power technology.

• The Eli Lilly Award in Medical and Biological Engineering to **Max Anliker** (nonmember) “for five decades of outstanding achievements and contributions to biological engineering.”

Anliker began his academic career in the department of aeronautics and astronautics at Stanford University in California. There he initiated a research program in biomechanics in collaboration with the National Aeronautics and Space Administration’s Ames Research Center. Since 1971 Anliker has been director of the Swiss Federal Institute of Technology (ETHZ)/University of Zurich Institute of Biomedical Engineering, where he has led interdisciplinary research projects involving the ETHZ and university clinics. Research has focused on developing noninvasive low-risk measuring procedures based on computer-assisted ultrasonic imaging and flow analysis, high-precision low-dose computed tomography for bone analysis, and thermography for breast cancer detection.

• The Jack A. Morton Award to **Toshihisa Tsukada** (F) “for contributions to the discovery and development of buried heterostructure (BH) semiconductor lasers.”

Tsukada joined Hitachi Ltd.’s Central Research Laboratory in Tokyo in 1968 and became senior chief scientist there in 1991. In 1974 he invented and developed the BH injection laser, the first point-source semiconductor laser with a low threshold current, a reproducible and stable transverse mode, the lowest-order TE_{00} mode, modulation in the gigahertz region, good thermal dissipation, high quantum efficiency, and high reliability. BH lasers are considered the most suitable lasers for long-distance, large-capacity communications systems.

• The Frederik Philips Award to **Max T. Weiss** (LF) “for leadership in building electronics research and engineering organizations for the development and operation of national security space systems.”

Weiss joined Northrop Corp., Los Angeles, in 1986, where he is corporate vice president and general manager of the Electronic Systems Division. Prior to Northrop, he spent 25 years at Aerospace Corp., El Segundo, CA, where he led the expansion of Aerospace’s R&D, and retired in 1986 as group vice president of engineering. Among his many achievements, as general manager of the Electronics and Optics Division for 10 years, he initiated establishment of failure analysis capabilities and an electronic component reliability data bank used in the development and timely launch of numerous space systems.

• The Emanuel R. Piore Award to **Makoto Nagao** (SM) “for leadership and contributions to natural language processing and computer vision areas.”

Nagao joined the electrical engineering faculty at Japan’s Kyoto University in 1961 and was named a professor in 1973. In the field of natural language processing, he proposed a powerful tree-to-tree transformation framework for a transfer-based machine translation system, and constructed a system that translates abstracts of scientific and technical papers from Japanese into English. Many of the machine translation systems used today in Japanese industry are based on this technology.

• The Judith A. Resnik Award to **Bonnie J. Dunbar** (M) “for significant contributions to the processing and development of electronic materials in space.”

An astronaut since 1981 and a mission specialist, Dunbar is also a materials scientist and engineer whose research interests lie in the effect of processing, particularly under microgravity, on intrinsic electrical properties. Currently, Dunbar is working with the University of Houston Space Vacuum Epitaxy Center on growing superconducting crystals in space. And she was the co-investigator for the microgravity science experiment that flew on the Space Shuttle Columbia mission in June 1992.

While at Rockwell International Space Division in the 1970s, she was instrumental in developing the ceramic tiles that enable

the Space Shuttle to survive re-entry. She joined the National Aeronautics and Space Administration in 1978 as a payload officer and flight controller.

• The David Sarnoff Award to **Rao R. Tummala** (SM) "for development of high-density, high-performance multichip packages for computer applications."

Tummala joined IBM Corp. as a staff engineer in 1968. Between 1976 and 1985, he pioneered the concept of glass-ceramic/copper multilayer ceramic technology, demonstrating the feasibility of sintered glass-ceramics with unique properties, cofiring multilayer copper metallization, and zero shrinkage for the substrate. The technology is currently used in all of IBM's high-performance computers.

• The Solid-State Circuits Award to **Kiyoo Itoh** (SM) "for technical contributions to folded data-line circuits and the development of high-density dynamic RAMs."

Senior chief scientist at Hitachi Ltd.'s Central Research Laboratory in Tokyo since 1991, Itoh has been a designer of eight generations of dynamic RAMs (DRAMs), ranging from 4K to 64M bits in size. In 1974 he pioneered the folded data- (or bit-) line circuit for DRAMs, which came into universal use because of its noise suppression and $V_{cc}/2$ sensing ability. For this he received the Prize of the Governor of Tokyo in 1988, the National Invention Award in 1989, and in 1990 the Outstanding Achievement Award of the Institute of Electronics, Information and Communication Engineers of Japan.

• The Charles Proteus Steinmetz Award to **Ivan Easton** (LF) "for technical and administrative leadership in the development of the IEEE standards program and the U.S. National Committee of the International Electrotechnical Commission (IEC)."

Easton retired in 1972 from General Radio Co., Englewood, FL, where he spent his entire career. (The company is now GenRad Inc., of Concord, MA.) He became vice president of engineering, and on retirement, was senior vice president and member of the Board of Directors. He served as consulting staff director of standards for the IEEE between 1976 and 1980 and as president of the U.S. National Committee of the IEC between 1980 and 1984. Following the merger of the Institute of Radio Engineers and the American Institute of Electrical Engineers in 1963, he chaired a committee to study integration of the two standards offices. The committee's report formed the basis of the IEEE Standards Department and serves as the current *modus operandi* of the Standards Board.

• The Nikola Tesla Award to **Madabushi V.K. Chari** (F) "for pioneering contributions to finite element computations of nonlinear electromagnetic fields for design and analysis of electric machinery."

Chari's contributions to nonlinear finite-element analysis have been applied to the design and optimization of electrical devices that include rotating electrical machines, power transformers, permanent-magnet machines, insulators, and surge arrestors. Chari joined General Electric Co.'s large steam turbine-generator department in Schenectady, NY, in 1970, and subsequently was responsible for advanced generator design, electromagnetic field studies, and computer-aided engineering. He moved to the company's Corporate Research and Development Center in 1976, where he did electromagnetic analysis and design of electric apparatus. He was manager of GE's electromagnetics program from 1979 until his retirement in 1992. He now serves GE as a consultant.

• The Graduate Teaching Award to **Rudolf Saal** (LF) "for inspired teaching, concerned guidance, and research supervision of electrical engineering graduate students."

Saal taught at the Technical University of Munich, in Germany, from 1961 until his retirement in 1988. He instituted new courses on fundamental network theory and advanced circuit design, and established the first complete graduate laboratory courses for hybrid-microelectronics in Germany. He also initiated the country's first full-custom very large-scale integration laboratory course to have a multiproject chip-fabrication facility.

• The Undergraduate Teaching Award to **Ronald Hoelzeman** (F) "for outstanding teaching, for his concern with students, and for his contributions to the quality of undergraduate electrical engineering education."

Hoelzeman is associate chair of electrical engineering at the University of Pittsburgh, where he has taught since 1970. He has developed courses and laboratories in circuits and linear systems, computer organization, logic design, and optimization techniques. He led the development of the Interactive Computing Laboratory, a computer-aided engineering instructional facility that emphasizes computer-aided design tools. ◆

Prize paper authors honored

The IEEE Board of Directors selected eight recipients of the 1993 prize paper awards. **Ilya W. Slutsker** (M), **William F. Tinney** (LF), and **Narasimham Vempati** (M) share the 1993 W.R.G. Baker Prize Award for their paper, "Enhancements to Givens' Rotations for Power System State Estimation," *IEEE Transactions on Power Systems*, Vol. 6, no. 2, May 1991.

Slutsker is a consultant in the development of advanced state estimation products for the Empros Division of Control Data Corp., Plymouth, MN. Joining the division as a senior engineer in 1984, he became team leader for the development of enhancements to the Givens' rotational form of the orthogonal transformation. The new method helps electric utilities operate security and optimization applications for handling electromagnetic susceptibility with greater accuracy and reliability.

Tinney joined the U.S. Department of Interior's (later, the Department of Energy's) Bonneville Power Administration, Portland, OR, in 1955. He remained there until he retired in 1979 as head of the system analysis section. His most important contribution was developing and advancing sparse matrix technology for the solution of power network problems. At Bonneville, the group he supervised pioneered in developing production software for power system computer applications. Tinney is now a consultant in Portland.

Vempati worked on the Empros team that investigated the use of orthogonal transformations using Givens' rotations. He joined the R&D group at Empros in 1988 and participated in the initial design and implementation of a topology processing toolkit for electric distribution systems. He is currently senior engineer at Empros Systems International, Minneapolis, MN.

• **Pravas R. Mahapatra** (nonmember) and **Dusan S. Zrnic** (F) share the Donald G. Fink Prize Award for their paper, "Sensors and Systems to Enhance Aviation Safety Against Weather Hazards," *Proceedings of the IEEE*, Vol. 79, no. 9, September 1991. This paper is the product of research carried out at the National Oceanographic and Atmospheric Administration's National Severe Storms Laboratory, Norman, OK.

Mahapatra has taught in the department of aerospace engineering at the Indian Institute of Science, Bangalore, since 1970. His research in aerospace and electronic systems has included investigations into radar systems, aerospace navigation theory, aircraft navigational aids, flight safety and weather phenomena, and air traffic control.

Zrnic has been associated with the National Severe Storms Laboratory since the 1970s, and in 1987 became manager of the Doppler Radar and Remote Sensing Research Group. He has made contributions to the theory and practice of signal processing for meteorological Doppler radar.

• **Anton T. Dahbura** (SM), **Ramsey W. Haddad** (nonmember), and **Anup B. Sharma** (nonmember) share the Browder J. Thompson Memorial Prize Award for their paper, "Increased Throughput for the Testing and Repair of RAMs with Redundancy," *IEEE Transactions on Computers*, Vol. 40, no. 2, February 1991.

Dahbura became research director of the Motorola Cambridge Research Center, Cambridge, MA, in 1990, in the area of parallel and distributed computing systems.

Since joining Digital Equipment Corp.'s Western Research Laboratory, Palo Alto, CA, in 1989, Haddad has been involved in systems, very large-scale integration computer-aided design, and architecture.

Sharma worked from 1988 to 1991 at the distributed systems research department of AT&T Bell Labs Computer Research Laboratory, Murray Hill, NJ. He is now with Salomon Brothers Inc., Rutherford, NJ, developing applications in a real-time distributed computing environment for equities trading.

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2 ADDITIONAL COMMENTS

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Void after November 1, 1993 *Void overseas December 1, 1993* **8/93**

The following unconventional product advisories are based on discoveries in physics that may affect product safety. They are taken from *Absolute zero gravity*, a collection of jokes, anecdotes, limericks, and riddles concerning the scientific community, written by Betsy Devine and Joel E. Cohen (Simon & Schuster, New York, 1992, pp. 123–24). The material originally appeared in "A Call for More Scientific Truth in Product Warning Labels," by Susan Hewitt and Edward Subitsky, *Journal of Irreproducible Results*, Vol. 36, January/February 1991, pp. 21–26 (reprinted by permission of Blackwell Scientific Publications Inc.). While no products yet bear these warnings, we fully expect them to be commonplace before the decade is out.

"WARNING: This Product Attracts Every Other Piece of Matter in the Universe, Including the Products of Other Manufacturers, with a Force Proportional to the Product of the Masses and Inversely Proportional to the Square of the Distance Between Them."

"HANDLE WITH EXTREME CARE: This Product Contains Minute Electrically Charged Particles Moving at Velocities in Excess of Five Hundred Million Miles Per Hour."

"ADVISORY: There Is an Extremely Small but Nonzero Chance That, Through a Process Known as 'Tunneling,' This Product May Spontaneously Disappear from Its Present Location and Reappear at Any Random Place in the Universe, Including Your Neighbor's Domicile. The Manufacturer Will Not Be Responsible for

"THIS IS A 100% MATTER PRODUCT: In the Unlikely Event That This Merchandise Should Contact Antimatter In Any Form, A Catastrophic Explosion Will Result."

"COMPONENT EQUIVALENCY NOTICE: The Subatomic Particles (Electrons, Protons, etc.) Comprising This Product Are Exactly the Same in Every Measurable Respect as Those Used in the Products of Other Manufacturers, and No Claim to the Contrary May Legitimately Be Expressed or Implied."

"IMPORTANT NOTICE TO PURCHASERS: The Entire Physical Universe, Including This Product, May One Day Collapse Back into an Infinitesimally Small Space. Should Another Universe Subsequently Re-Emerge, the Existence of This Product in That Universe Cannot Be Guaranteed."

Deciphering encryption

Reader Oskar Stürzinger writes from Monte Carlo to take issue with the use of the word *decryption* as the opposite of *enciphering*.

...at the word is unnecessary ...nd that the terms *encipher* ...re in use long before cryp- ...on the scene. He puts the ...w terms on "computer peo- ...ople in their ivory tower of ...] have no knowledge of ...cryptographic side."

...peaking loves a challenge, ...ent us scurrying to the ...*h Dictionary* to decipher ...terms. The English word ...most directly from the ..., meaning number, but it ...s through *çifr*, Arabic for ...skrit word *sunya*, meaning ...ionary defines cipher as "a ...uised manner of writing, ...racters arbitrarily invented, ...other than their ordinary ...b, cipher has two meanings: to solve by arithmetic and to express in secret writing.

The Greek prefix *crypto*, meaning "hidden," has been a part of the English language since the mid-1600s. The *Oxford English Dictionary* defines cryptography as "generally, the art of writing or solving ciphers" and a cryptogram as "a piece of cryptographic writing; anything written in cipher." The dictionary shows one of the first uses of *decrypt* to have occurred in 1936, with the meaning of solving a cryptogram with or without a key. While the words *encrypt* and *encryption* are seen in various texts, the dictionary does not show either of them as a legitimate word. Stürzinger's assertion that decryption is an artifact of the "computer people" cannot be proven, therefore, but it appears that it may have some merit.

Technically Speaking is intended as a commentary on the use and misuse of technical language and culture, both within the scientific/engineering community and by the general public. Because few who care about the subject are neutral, this column will probably be seen as a laudable effort, badly misinformed, stunningly correct, essential, trivial, or any combination of the above. Comments, commendations, and condemnations will be accepted, often cheerfully. Pet peeves are of particular interest. Readers are invited to reply by mail, care of Technically Speaking, or by e-mail to klself@mcimail.com.

Contributing Editor Kevin Self (M) surveys the etymological world from his workstation at Texas Microsystems Inc., Houston, TX.

CONSULTANT: Anne Eisenberg, Polytechnic University

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• The Solid-State Circuits
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Senior chief scientist
Central Research Laborato
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he pioneered the folded d
circuit for DRAMs, which came into universal use because of its noise suppression and $V_{cc}/2$ sensing ability. For this he received the Prize of the Governor of Tokyo in 1988, the National Invention Award in 1989, and in 1990 the Outstanding Achievement Award of the Institute of Electronics, Information and Communication Engineers of Japan.

• The Charles Proteus Steinmetz Award to **Ivan Easton** (LF) "for technical and ad-

and analysis of electric machinery."

Chari's contributions to nonlinear finite-element analysis have been applied to the design and optimization of electrical devices that include rotating electrical machines, power transformers, permanent-magnet machines, insulators, and surge arrestors. Chari joined General Electric Co.'s large steam turbine-generator department in Schenectady, NY, in 1970, and subsequently was responsible for advanced generator

graduate electrical engineering education."

Hoelzeman is associate chair of electrical engineering at the University of Pittsburgh, where he has taught since 1970. He has developed courses and laboratories in circuits and linear systems, computer organization, logic design, and optimization techniques. He led the development of the Interactive Computing Laboratory, a computer-aided engineering instructional facility that emphasizes computer-aided design tools. ◆

Prize paper authors honored

The IEEE Board of Directors selected eight recipients of the 1993 prize paper awards. **Ilya W. Slutsker** (M), **William F. Tinney** (LF), and **Narasimham Vempati** (M) share the 1993 W.R.G. Baker Prize Award for their paper, "Enhancements to Givens' Rotations for Power System State Estimation," *IEEE Transactions on Power Systems*, Vol. 6, no. 2, May 1991.

Slutsker is a consultant in the development of advanced state estimation products for the Empros Division of Control Data Corp., Plymouth, MN. Joining the division as a senior engineer in 1984, he became team leader for the development of enhancements to the Givens' rotational form of the orthogonal transformation. The new method helps electric utilities operate security and optimization applications for handling electromagnetic susceptibility with greater accuracy and reliability.

Tinney joined the U.S. Department of Interior's (later, the Department of Energy's) Bonneville Power Administration, Portland, OR, in 1955. He remained there until he retired in 1979 as head of the system analysis section. His most important contribution was developing and advancing sparse matrix technology for the solution of power network problems. At Bonneville, the group he supervised pioneered in developing production software for power system computer applications. Tinney is now a consultant in Portland.

Vempati worked on the Empros team that investigated the use of orthogonal transformations using Givens' rotations. He joined the R&D group at Empros in 1988 and participated in the initial design and implementation of a topology processing toolkit for electric distribution systems. He is currently senior engineer at Empros Systems International, Minneapolis, MN.

• **Pravas R. Mahapatra** (nonmember) and **Dusan S. Zrnic** (F) share the Donald G. Fink Prize Award for their paper, "Sensors and Systems to Enhance Aviation Safety Against Weather Hazards," *Proceedings of the IEEE*, Vol. 79, no. 9, September 1991. This paper is the product of research carried out at the National Oceanographic and Atmospheric Administration's National Severe Storms Laboratory, Norman, OK.

Mahapatra has taught in the department of aerospace engineering at the Indian Institute of Science, Bangalore, since 1970. His research in aerospace and electronic systems has included investigations into radar systems, aerospace navigation theory, aircraft navigational aids, flight safety and weather phenomena, and air traffic control.

Zrnic has been associated with the National Severe Storms Laboratory since the 1970s, and in 1987 became manager of the Doppler Radar and Remote Sensing Research Group. He has made contributions to the theory and practice of signal processing for meteorological Doppler radar.

• **Anton T. Dahbura** (SM), **Ramsey W. Haddad** (nonmember), and **Anup B. Sharma** (nonmember) share the Browder J. Thompson Memorial Prize Award for their paper, "Increased Throughput for the Testing and Repair of RAMs with Redundancy," *IEEE Transactions on Computers*, Vol. 40, no. 2, February 1991.

Dahbura became research director of the Motorola Cambridge Research Center, Cambridge, MA, in 1990, in the area of parallel and distributed computing systems.

Since joining Digital Equipment Corp.'s Western Research Laboratory, Palo Alto, CA, in 1989, Haddad has been involved in systems, very large-scale integration computer-aided design, and architecture.

Sharma worked from 1988 to 1991 at the distributed systems research department of AT&T Bell Labs Computer Research Laboratory, Murray Hill, NJ. He is now with Salomon Brothers Inc., Rutherford, NJ, developing applications in a real-time distributed computing environment for equities trading.

Technically speaking

And now new warning labels triggered by physics

Kevin Self

The safety of the products we engineers design should matter as much to us as their usefulness. Although our desire to develop safe products should reflect our dedication to the ethics of our profession, an undoubted factor is the legal liability for faulty products.

Traditionally, product designers have been concerned about the effects of classical Newtonian physics, warning consumers of a product's chances of catching fire or exploding or generating a shock. The onward march of quantum mechanics, however, raises new questions as to how informed consumers should be about the products they buy—and how best to describe potential dangers.

The following unconventional product advisories are based on discoveries in physics that may affect product safety. They are taken from *Absolute zero gravity*, a collection of jokes, anecdotes, limericks, and riddles concerning the scientific community, written by Betsy Devine and Joel E. Cohen (Simon & Schuster, New York, 1992, pp. 123–24). The material originally appeared in "A Call for More Scientific Truth in Product Warning Labels," by Susan Hewitt and Edward Subitsky, *Journal of Irreproducible Results*, Vol. 36, January/February 1991, pp. 21–26 (reprinted by permission of Blackwell Scientific Publications Inc.). While no products yet bear these warnings, we fully expect them to be commonplace before the decade is out.

"WARNING: This Product Attracts Every Other Piece of Matter in the Universe, Including the Products of Other Manufacturers, with a Force Proportional to the Product of the Masses and Inversely Proportional to the Square of the Distance Between Them."

"HANDLE WITH EXTREME CARE: This Product Contains Minute Electrically Charged Particles Moving at Velocities in Excess of Five Hundred Million Miles Per Hour."

"ADVISORY: There Is an Extremely Small but Nonzero Chance That, Through a Process Known as 'Tunneling,' This Product May Spontaneously Disappear from Its Present Location and Reappear at Any Random Place in the Universe, Including Your Neighbor's Domicile. The Manufacturer Will Not Be Responsible for Any Damages or Inconvenience That May Result."

"NOTE: The Most Fundamental Particles in This Product Are Held Together by a 'Gluing' Force About Which Little Is Currently Known and Whose Adhesive Power Can Therefore Not Be Permanently Guaranteed."

"ATTENTION: Despite Any Other Listing of Product Contents Found Hereon, the Consumer Is Advised That, in Actuality, This Product Consists of 99.9999999999% Empty Space."

"THIS IS A 100% MATTER PRODUCT:

In the Unlikely Event That This Merchandise Should Contact Antimatter In Any Form, A Catastrophic Explosion Will Result."

"COMPONENT EQUIVALENCY NOTICE: The Subatomic Particles (Electrons, Protons, etc.) Comprising This Product Are Exactly the Same in Every Measurable Respect as Those Used in the Products of Other Manufacturers, and No Claim to the Contrary May Legitimately Be Expressed or Implied."

"IMPORTANT NOTICE TO PURCHASERS: The Entire Physical Universe, Including This Product, May One Day Collapse Back into an Infinitesimally Small Space. Should Another Universe Subsequently Re-Emerge, the Existence of This Product in That Universe Cannot Be Guaranteed."

Deciphering encryption

Reader Oskar Stürzinger writes from Monte Carlo to take issue with the use of the word *decryption* as the opposite of *enciphering*. He contends that the word is unnecessary and confusing, and that the terms *encipher* and *decipher* were in use long before cryptologists came on the scene. He puts the blame for the new terms on "computer people... as these people in their ivory tower of informatics [sic] have no knowledge of terms from the cryptographic side."

Technically Speaking loves a challenge, and this one sent us scurrying to the *Oxford English Dictionary* to decipher these cryptic terms. The English word *cipher* comes most directly from the French *chiffre*, meaning number, but it traces its roots through *çifr*, Arabic for zero, to the Sanskrit word *sunya*, meaning empty. The dictionary defines cipher as "a secret or disguised manner of writing, whether by characters arbitrarily invented, or characters in other than their ordinary sense." As a verb, cipher has two meanings: to solve by arithmetic and to express in secret writing.

The Greek prefix *crypto*, meaning "hidden," has been a part of the English language since the mid-1600s. The *Oxford English Dictionary* defines cryptography as "generally, the art of writing or solving ciphers" and a cryptogram as "a piece of cryptographic writing; anything written in cipher." The dictionary shows one of the first uses of *decrypt* to have occurred in 1936, with the meaning of solving a cryptogram with or without a key. While the words *encrypt* and *encryption* are seen in various texts, the dictionary does not show either of them as a legitimate word. Stürzinger's assertion that decryption is an artifact of the "computer people" cannot be proven, therefore, but it appears that it may have some merit.

Technically Speaking is intended as a commentary on the use and misuse of technical language and culture, both within the scientific/engineering community and by the general public. Because few who care about the subject are neutral, this column will probably be seen as a laudable effort, badly misinformed, stunningly correct, essential, trivial, or any combination of the above. Comments, commendations, and condemnations will be accepted, often cheerfully. Pet peeves are of particular interest. Readers are invited to reply by mail, care of Technically Speaking, or by e-mail to klself@mcimail.com.

Contributing Editor Kevin Self (M) surveys the etymological world from his workstation at Texas Microsystems Inc., Houston, TX.

CONSULTANT: Anne Eisenberg, Polytechnic University

Faults & failures

The worm turns

At least 30 people have been electrocuted over the past 20 years by a simple, commercially available electric appliance—a probe used to harvest earthworms for live fishing bait.

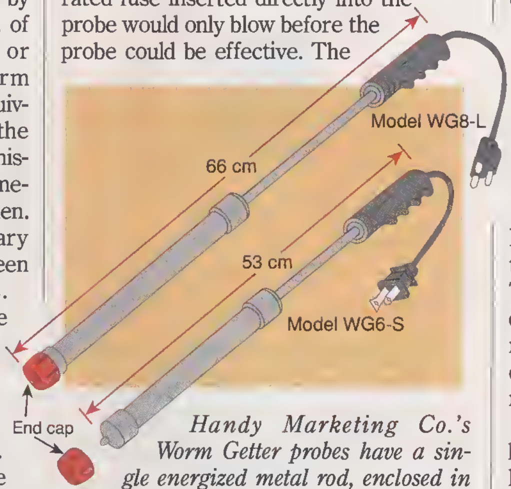
The device consists of a metal rod connected to the hot side of household electricity. The circuit is completed by inserting the rod into the earth. The shocked worms rise to the surface, where they can be easily collected.

Citing the deaths and the inherent danger of the probes, the U.S. Consumer Product Safety Commission (CPSC), Washington, DC, recently announced the recall of the only current commercial version—the Worm Getter, manufactured by the now defunct Handy Marketing Co. of Grand Rapids, MI. While no deaths or injuries have been attributed to Worm Getters, the devices are functionally equivalent to the lethal units, according to the announcement by the CPSC. The commission is especially concerned about homemade probes built by ingenious fishermen. They usually lack the most rudimentary safety features, and some have even been found to have no insulating handles. These units are the cause of many of the reported deaths.

The very simplicity of the probe—it is fundamentally just an extremely low-resistance path between 120 V and ground—is what makes it so dangerous. In normal operation, with the probe inserted into the soil, several amperes of current can flow. (The exact amount depends mainly on the resistance between the probe and the soil.) If a person is inserted into the electrical loop, the resistance goes up significantly, with a corresponding drop in current. But current levels of only a few milliamperes can be fatal to human beings. The electrical resistance of a person is typically in the kilohm range but varies widely with the size and composition of the body and the moisture content of the skin. Children are especially vulnerable and, in fact, form most of the fatalities reported to the commission. The resistance of the person's contact with the ground is also a big factor. The type of shoes worn and the wetness of the soil can make a life-or-death difference.

Designers of the Worm Getter probe attempted to make the product safe by shielding a user from contact with its metal parts [see figure]. They covered the shaft's upper section with a thin transparent plastic sleeve and its lower portion with a hard plastic sheath that retracts when the probe is pushed into the ground. A cap at the end of the shaft covers the probe tip. Under normal use, though, the cap would be removed. And there is nothing to prevent a user from manually retracting the sheath and grasping the rod.

The operating principle of the worm probe makes it hard for the manufacturer to provide safeguards. Two common safety precautions are completely ineffective. Reducing the voltage could make the probes safer for humans; but it also makes them safer for the worms, which apparently remain unmoved by the lower currents. Fuses also will not work. Household fuses and circuit breakers are usually rated at 10-20 A, many times the fatal level. A lower-rated fuse inserted directly into the probe would only blow before the probe could be effective. The same reasons make the use of ground-fault circuit interrupters ineffective. The worm probes themselves are ground faults.



Handy Marketing Co.'s Worm Getter probes have a single energized metal rod, enclosed in plastic, that is pushed into the ground after the end cap is removed. A black plastic bicycle grip serves as a handle. The power cord is 20 cm long, and an extension cord is needed to connect it to an electrical receptacle. Model WG6-S has a two-prong plug, and WG8-L has a three-prong plug with an indicator light.

There is one approach that could help, according to Tim Jones, CPSC compliance officer. A probe that pulsed the current—say every second or so—might allow a person who had accidentally grasped the probe's shaft to let go before he or she was electrocuted. But Jones has not seen any commercial worm probes with this feature.

Although all the fatalities have been persons who touched the metal rod itself, the commission has even received reports of electric shocks to persons touching the ground near the probe. According to Jones, measurements taken within 15 cm of the probe have shown ground currents to be unacceptably high, and are one of the main reasons for the present recall. Details of the ground-current study may be obtained from the commission's Freedom of Information Officer.

This is not the first time that the commission has ruled against worm probes. In 1991, after a lengthy court battle, the commission ordered P&M Enterprises of Caldwell, ID, to halt the manufacture and sale of its Worm Gett'rs. This probe operates on the same principle as the Worm Getter, but contains 2, 6, or 12 bare metal shafts with unfinished wooden handles. The shafts are pushed into the ground over an area. By the time the ban could be enforced, P&M Enterprises was bankrupt, so no recall could be ordered.

Handy Marketing is out of business, too. So six retailers who sold the Worm Getter have agreed to carry out the recall. Except for KMart, the retailers sold the units mainly through mail-order catalogs.

About 30 000 of the P&M Worm Gett'r probes have been sold since 1983. Handy Marketing manufactured more than 80 000 of its probes from 1980 on. The cost ranged from US$8 to $28, depending on the model. Tim Jones worries that the probes, which are simple and durable, could be around for a while, and result in more deaths.

Although the CPSC recognizes the inherent danger of these products, it does not have any authority for premarket clearance, according to Stacey Rubin-Mesa, the commission's public affairs specialist. Each new product is examined as it comes on the market, and only then banned if found dangerous.

"The idea for worm probes has been around for 50 years," said Jones. "And it's an idea that doesn't die easily." One enterprising individual was selling instructions for making the probes, according to Jones. The commission ordered him to stop and to send warnings to those who had purchased the instructions.

The 30 deaths due to the probes are a tiny fraction of deaths from electric current, which number more than 700 per year in the U.S. But with a device so simple that it can be made at home, the blame must lie, at least in part, with popular ignorance of the hazards of household electricity. Some people may even believe that household fuses will protect them, according to Jones. Learning otherwise could prove fatal.

COORDINATOR: Linda Geppert

CLASSIFIED EMPLOYMENT OPPORTUNITIES

The following listings of interest to IEEE members have been placed by educational, goverment, and industrial organizations as well as by individuals seeking positions. To respond, apply in writing to the address given or to the box number listed in care of *Spectrum* Magazine, Classified Employment Opportunities Department, 345 E. 47th St., New York, N.Y. 10017.

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Positions open—$36.00 per line, not agency-commissionable

Positions wanted—$36.00 per line, a 50% discount for IEEE members who supply their membership numbers with advertising copy.

All classified advertising copy must be received by the 25th of the month, two months preceding the date of issue. No telephone orders accepted. For further information call 212-705-7578.

IEEE encourages employers to offer salaries that are competitive, but occasionally a saslary may be offered that is significantly below currently acceptable levels. In such cases the reader may wish to inquire of the employer whether extenuating circumstances apply.

Academic Positions Open

Princeton University: The Department of Electrical Engineering invites applications for a full time tenure-track faculty position in the area of optics and advanced photonic materials, devices or systems. Materials, devices or architectures work should concentrate on their application to ultra high bandwidth or high density photonic systems. Examples include semiconductor lasers, ultrahigh bandwidth integrated circuits, III-V and II-VI photonic device fabrication and characterization, optoelectronic integrated circuits, integrated optics, optical/materials interactions, photorefractive and nonlinear optical materials and devices, and optical architectures including computers, neural nets, signal processors, etc. Candidates should have a desire for working in a group environment on collaborative projects with new scientific objectives and content. Please send a complete resume, a description of research and teaching interests, and names of three references to Professor Stuart Schwartz, Chair, Dept. of EE, Princeton University, Princeton, NJ 08540-5263. Princeton University is an equal opportunity/affirmative action employer.

Grad Student Ph.D. Assistantships open for only highly experienced engineers in the power quality area. Send resume with refs and GRE to Dr. Alex Domijan, Director, Florida Power Affiliates, Dept. of Electrical Engineering, Univ. of Florida, 323 Benton Hall, Gainesville, FL 32611, (904)392-0290.

Joint Faculty Position in School of Engineering Science and Department of Physics. The School of Engineering Science and the Department of Physics invite applications for a joint tenure-track position as Assistant Professor, effective September 1, 1994 or earlier. The successful applicant will have a background in electrical engineering and a strong record of research in the design, and/or fabrication of advanced compound semiconductor electronic or photonic devices. Working with current faculty members, he or she will teach at the graduate and undergraduate levels in Engineering Science, supervise student projects and theses, and participate in industrial interactions. Prior industrial experience is an asset. Engineering Science and Physics together provide an exciting educational environment with very high academic standards and an outstanding record of grant and contract funding. A state-of-the-art MOCVD growth system will be commissioned this year as phase one of a major funded initiative of the two departments. Local industry offers many opportunities for collaborative research, and strong industrial links are characteristic of the program and expected of faculty members. This academic environment is balanced by the natural and cultural ambience of one of the most attractive cities in North America. The university itself enjoys a spectacular mountaintop setting, a short drive from downtown Vancouver. This position is subject to final budgetary authorization. Simon Fraser University is committed to the principle of equity in employment and offers equal opportunities to qualified applicants. To apply, send a curriculum vitae, copies of your three most significant papers and the names of three references to Dr. J.K. Cavers, Director, School of Engineering Science, Simon Fraser University, Burnaby, B.C., V5A 1S6, Canada, by September 30, 1993.

Cornell University – Faculty Position. The School of Electrical Engineering at Cornell University has openings in computer engineering. Applications are invited at all levels, but we are especially interested in making senior appointments. Applicants should have strong commitments to and outstanding achievements in research and teaching. We are particularly interested in individuals investigating the coupling of high bandwidth communications with high capacity computation. The candidate's general research areas may include one or more of the following: processor and system architectures; distributed and parallel processing; design of VLSI systems. Interested persons should submit a letter of application, professional resume, and the names of at least four references to: Director, School of Electrical Engineering, 224 Phillips Hall, Cornell University, Ithaca, NY 14853-5401. Cornell University is an Affirmative Action/Equal Opportunity Employer.

Senior Scientist, Ames Laboratory, Iowa State University. The Applied Mathematical Sciences Research Program at the Ames Laboratory is seeking a senior level scientist to provide direction and leadership for scientific projects of national and international impact in the scientific area of direct and inverse scattering. Position requires a Ph.D in Applied Mathematics, Mathematics, or related field plus ten years of related research experience. Experience must include writing research proposals that have led to funding, supervising graduate students and support staff, and written and oral presentations of research work. Salary commensurate with qualifications. Send cover letter, resume, plus the names and addresses of three references to: Ames Laboratory Personnel Office, 127 Spedding Hall, Iowa State University, Ames, IA 50011. Application deadline of August 15, 1993. An equal opportunity/affirmative action employer.

Electrical Engineering. The Department of Electrical Engineering at McGill University has a limited term opening for a Research Associate to participate in research on Free-Space Digital Optics. Applicants should have a relevant Ph.D. and experience in the design and construction of optical and optomechanical systems based on the SEED technology. This background should also include experience in developing and demonstrating holographic optical interconnection systems. The appointment is for an initial period of one year with possibility of extension for up to a total of three years. A starting date of September 1, 1993 or as soon as possible thereafter is expected. Enquiries including an updated Curriculum Vitae and the names of at least three references should be sent to Professor H. Scott Hinton, Department of Electrical Engineering, McGill University, 3480 University Street, Montreal, Quebec H3A 2A7, Canada. In accordance with Canadian Immigration requirements, this advertisement is directed to Canadian citizens and permanent residents of Canada. McGill University is committed to equity in employment.

The Department of Aeronautics and Astronautics at Stanford University seeks an outstanding person for an appointment as Professor Research (non-tenure track) to perform research in the field of Satellite Based Vehicle Positioning and related technologies. The selected individual will help lead a program to explore techniques and applications of centimeter level vehicle positioning. Stanford is a world leader in this field of research. Particular emphasis includes: Precise aircraft landing, Smart highways, Air and ground traffic control and Heavy equipment positioning. Qualifications include specific in-depth knowledge of GPS, automatic controls, signal processing, electromagnetic propagation and ICAO aircraft landing requirements. A proven leadership record in obtaining sponsored research is essential. Prior experience with FAA or NASA is desirable. Individual should have an earned engineering Doctorate in EE, Aero Astro or ME. Stanford is an Affirmative Action employer and welcomes applications from women and minority candidates. Deadline for applications is September 15, 1993. Applications should be sent to: Professor Bradford W. Parkinson, Aeronautics and Astronautics, Gravity Probe-B, Hansen Experimental Physics Laboratory, Stanford University, CA 94305-4085.

Research Chair in Optoelectronic Architectures, Department of Electrical Engineering, University of Ottawa, Canada. The University of Ottawa, the Ottawa Carleton Research Institute (OCRI), the Telecommunications Research Institute of Ontario (TRIO), and industrial partners (including Bell-Northern Research (BNR)) seek qualified applicants for the OCRI Industrial Research Chair in Architectures and Methodology for Advanced Optical/Electronic Networks to be submitted for matching funding from the Natural Sciences and Engineering Research Council of Canada (NSERC). Ottawa is Canada's capital and is often referred to as "Telecom Valley", because of the large concentration of telecommunications companies in the area, led by BNR. This Chair is one of six sponsored by OCRI in the Ottawa area and is aimed at enhancing the research excellence in the two local Universities and their interaction with industry. This is a tenure-track position. The successful candidate will be appointed at the Full Professor level in the Department of Electrical Engineering at the University of Ottawa, a major bilingual university in Canada and a principal partner in the Ottawa-Carleton Institute for Electrical Engineering and two Centers of Excellence, the Telecommunications Research Institute of Ontario (TRIO) and the Canadian Institute of Telecommunications Research (CITR). The Department of Electrical Engineering has currently 23 full-time professors, including 2 Research Chairs, 15 adjunct professors, 120 graduate students, 400 undergraduate students and annual research funding exceeding $3 million. The Chairholder will interact, amongst others, with the Photonic Networks and Multimedia Communications Research Laboratories of the Department, currently composed of more than 60 researchers, funded at an annual rate of $2 million and carrying leading-edge research in the area. The Chair award will include funding for a research associate, graduate students and equipment. Extensive laboratories for research in optical communications and other fields related to the Chair are available. The Chairholder and the research team will interact with the industrial sponsors of the Chair. The Chairholder will have reduced teaching load. Requirements: Candidates should have a Ph.D. in Electrical or Computer Engineering. Experience in research and development of Optical Communications Networks and High-speed Networking Systems is required. The candidate should have at least five years experience in or with an industrial environment and have successfully conducted, as a group leader, advanced research and development projects in the above domain. The candidate should present evidence of scientific productivity and quality either through refereed publications or other indicators more appropriate to an industrial background (e.g., patents, technical reports, etc). Interest in training graduate students and researchers and ability to work in a team and provide leadership are mandatory. Employment equity is a University policy. In accordance with Canadian Immigration laws, priority will be given to Canadian Citizens or permanent residents. Applications, including a detailed curriculum

vitae and names of three references should be sent to: The Dean, Faculty of Engineering, University of Ottawa, Ottawa, Ontario, Canada, K1N-6N5. Tel.+1-(613)-564-8222, Fax: +1-(613)-564-7681.

Postdoctoral Scientific Research Opportunities in India. 3-12 month fellowships in India awarded to U.S. citizens. For information, contact: Jeanine Marie Greene, Academy for Educational Development, 1255 23rd Street, NW, Washington, D.C. 20037.

Florida Atlantic University invites applications for two tenure track positions at the level of Assistant Professor in the Center for Applied Stochastics Research. A successful applicant will hold a joint appointment in one of the departments in the College of Engineering, which consists of Computer Science and Engineering, Electrical Engineering, Mechanical Engineering, and Ocean Engineering. Candidates for each position should have an earned doctoral degree, with a strong background in stochastic processes as applied to one or more of the traditional disciplines in engineering. Interested applicants should send a current resume including names, addresses and telephones numbers of three references to Dr. Y. K. Lin, Director, Center for Applied Stochastics Research, Florida Atlantic University, Boca Raton, FL 33431. Deadline for application is September 30, 1993. Florida Atlantic University is a member of the Florida State University System and is an Equal Opportunity (M/F) Employer. Members of protected classes are encouraged to apply.

Electrical and Computer Engineering. The University of Alabama at Birmingham (UAB) seeks qualified candidates for one or more anticipated faculty positions in the Department of Electrical and Computer Engineering. All ranks will be considered. A successful candidate will be expected to contribute to the department in the areas of teaching, research, and service. A candidate should have an earned doctorate in electrical engineering and an established record of teaching and scholarship. Since the department has emphases in the areas of process instrumentation, industrial control, digital systems, communications, electronic power systems, and biomedical instrumentation, preference will be given to candidates having an expertise in one of these areas. Preference will also be given to candidates who have relationships with industry and are registered as Professional Engineers. The search will continue until the available positions are filled. For consideration, a candidate should send a detailed resume (including teaching experience, research plan, and the names, addresses, and telephone numbers of five references) to Dr. Gregg L. Vaughn, P.E., Department of Electrical and Computer Engineering, 1150 Tenth Avenue South, Birmingham, AL 35294-4461. UAB is an AA/EO employer.

Faculty Position in Electrical Engineering, California Institute of Technology. The Electrical Engineering Department at Caltech invites applications for tenure-track positions as Assistant Professor. The term of the initial appointment is normally four years and is contingent upon completion of PhD. Exceptionally qualified senior applicants may also be considered. We are especially interested in applicants from the area of Electrical Systems, i.e., Communications, Control, and Signal Processing. We are seeking highly qualified candidates who are committed to a career in research and teaching. Applicants should submit a resume, a one-page statement of research accomplishments and plans, three letters of recommendation, and up to five of their most significant conference or journal publications to: Professor R.J. McEliece, Chairman, EE Search Committee, Department of Electrical Engineering (116-81), California Institute of Technology, Pasadena, CA 91125. Caltech is an Equal Opportunity/Affirmative Action Employer. Women and minorities are encouraged to apply.

Professorships. The Toyota Technological Institute (TTI), established in 1981 by a donation from the Toyota Motor Corporation, offers undergraduate and master's degree programs. To further strengthen education and research at the graduate level, TTI is adding a doctoral program which will focus on the following disciplines; Information Aided Technology, including Advanced Information Theory, Information Processing, Information/Motion Transformation Theory, Thermofluid Dynamics, Intelligent Design, and Information Integrated Realization Technology. Future Industry-oriented Basic Science and Materials including Ultimate Structure & Properties, Molecular Design; Characterization & Properties, Noble Crystals & Semiconductors, Structure-Controlled Materials, Singular Layers in Materials, and Beam Processing. To commence this ambitious effort, TTI is currently seeking 5-8 senior faculty members at the full professor level to join this distinguished community by April 1, 1995. Selected individuals will organize a unit laboratory, which consist of 1 professor, 1 associate professor, 2-3 post doctoral research associates and students. Support for research start-up expenses and an annual research budget will be provided, in addition to a salary and fringe benefit package. Details will be provided upon inquiry. Qualified applicants are invited to send their curriculum vitae, a statement of research interests and a list of publications, by Oct. 30, 1993, to: Dr. M. Nagasawa, Vice President, Toyota Technological Institute, 2-12-1 Hisakata, Tenpaku-ku, Nagoya, Aichi 468, Japan. You may also inquire by Fax to Japan 81-52-802-6069. An Equal Opportunity Employer.

Tenure Track Faculty Position, University of Notre Dame. The Department of Electrical Engineering invites applications in the area of Electronic Materials and Devices. Special attention will be given to individuals specializing in materials processing and characterization, opto-electronics, microwave devices, and integrated circuits. Applicants should have a Ph.D. in Electrical Engineering or a related field. The Department offers B.S., M.S., and Ph.D. programs in Electrical Engineering. Active research areas include semiconductor device and integrated circuit fabrication, nanoelectronics, integrated optics, and computational electronics. Applicants should have interest in teaching at the undergraduate and graduate levels, advising students, and conducting research. Rank and salary are negotiable. Interested persons should submit a complete resume and names of three references to: Dr. Daniel J. Costello, Chairman, Department of Electrical Engineering, University of Notre Dame, Notre Dame, Indiana 46556. The University of Notre Dame is an Affirmative Action/Equal Opportunity Employer.

Government/Industry Positions Open

Software Design Engineer; By August 31, 1993; Please send resume to: Employment Security Department, E&T Division, Job # 372246-R, P.O. Box 9046, Olympia, WA 98507-9046. Job Description: Designs, implements and tests complex software for micro computers under limited supervision. Designs and implements Arabic and Hebrew versions of operating system software and Arabic and Hebrew versions of relational database management system and VisualBasic programming language products, including bi-directional handling, Arabic character display, and bi-lingual text handling features. Utilizes "C" and 286/386 Assembly programming languages, and MS-DOS operating system. Requirements: Master's degree in Electrical Engineering, Computer Science, Mathematics or Physics; 2 years of work experience in design and implementation of Arabic operating system shell software, Arabic word processing applications, and Arabic relational database management systems software for personal computers, including design and implementation of Arabization algorithms. Must include 6 months work experience in programming or computer software design utilizing "C", BASIC and 286/386 Assembly languages and MS-DOS operating system. Experience may be gained concurrently. Must be fluent in English and in reading and writing Arabic. Must have legal authority to work in the United States. Job Location: Seattle Area Employer. Salary: $48,300-$50,300 per annum, depending on experience. Compensation package includes bonuses and stock options. 40 hours per week, flex time. 2 positions available. EOE

Senior Design Engineer. Senior Design engineer for mfgr in NE Ohio. Design of remanufactured core & shell form transformers in the 500 kv class. Develop design computer programs for most core & shell form styles. Using computer analysis & modeling, develop & implement new winding & insulation configurations. Interpret customer specs to engrg. team. Provide material estimation, winding configurations & project input for predesign & proposal stages. M.S. required in Mechanical or Electrical Engrg. Must have 6 yrs. experience in multi-winding, multi-loaded short circuit current calculations & performance predictions for complex power transformers & in design of directed oil flow power transformers. 40 hrs/wk, 8 am - 5 pm, Mon-Fri. $60,000/yr. Must have proof of legal authority to work indefinitely in U.S. Send resume in duplicate (no calls) to J. Davies, JO#1385429, Ohio Bureau of Employment Services, PO Box 1618, Columbus, OH 43216.

Electrical Engineer: Technical support for litigation related to power distribution systems, equipment control systems, lighting, electrocutions and fires of electrical origin. Mature professional; effective communicator; part time assignments leading to full time employment from Lancaster and Albany, NY offices. Send resume to: Smith & Robson, Inc., Forensic Engineers, Architects and Scientists, 354 N. Prince St., Lancaster, PA 17603.

Engineer, Senior CAD: Develop & characterize advanced equipment models for VLSI & ULSI IC design, integration, control & diagnosis, including Low Pressure Chemical Vapor Deposition (LPCVD), Rapid Thermal Processing (RTP), plasma deposition & plasma etching processes; develop models for semiconductor manufacturing control & top-down process design & integration; develop simplified/compact models; define operating windows; responsible for the determination of film growth/etch rate, wafer temperature distribution, reactor gas flow, chemical reactions & ions/electrons motion & flux density distribution as a function of input equipment parameters. Ph.D. in Chemical Engineering. Academic project/research background in: plasma reactor modeling including kinetic theory & plasma dynamics; reaction engineering, kinetics, reactor design, momentum, heat, and mass transport and thermodynamics for chemical processes; process control; statistical & reaction kinetic theory; development of new numerical techniques based on finite differences & finite elements, including 2-D/3-D & transient solutions; applied analytical techniques for differential equations; code development and vectorization optimization and parallelization for multi-processor supercomputers; software packages including SAS & IMSL; commercial codes for fluid & thermodynamics applications; UNIX OS & FORTRAN. $5,078/; 40 hrs./wk. Place of employment and interview: Santa Clara, CA. If offered employment, must show legal right to work. Send this ad and your resume to: Job No. MN32122, P.O. Box 269065, Sacramento, CA 95826-9065. The company is an equal opportunity employer and fully supports affirmative action practices.

Microwave Design Engineer - Microwave Distance Measuring Equipment. Milltronics of Peterborough Canada seeks a Physics or Electrical Engineer experienced in microwave equipment design of 10 Ghz or higher. Thoroughly conversant with wave propagation in different media, you will apply your theoretical training to both microwave antenna and hardware design including transmitters, receivers, mixers and oscillators. We seek expertise in computer simulation of wave propagation and electronic circuits, nonlinear modelling and hands-on experience with microstrip antennas. Exposure to laboratory measurement in antenna polar patterns and microwave circuit patterns such as gain and noise is essential. Working closely with our corporate marketing and engineering groups, you will determine equipment specifications and source suppliers. You will also develop appropriate designs, assemble prototypes and verify those designs against agreed upon specifica-

tions. Fully responsible for scheduling resource needs, you will set and meet project objectives, recommend overall design direction and work with support staff involved with all aspects of product development from inception to final implementation. Milltronics is a leading Canadian owned international process measurement company located in Peterborough, Ontario, Canada. With a well-earned reputation for technical innovation and top quality products, we have enjoyed strong steady growth around the world since 1954. Please contact Claude Boily, Mgr. Human Resources, Milltronics, 730 The Kingsway, Box 4225, Peterborough, Ontario, Canada, K9J 7B1. Fax (705) 745-0414.

Engineer, Senior Process: Conduct research and development into materials, properties and processes for novel MOS structures & advanced logic devices; evaluate the relationship between the microstructure of thin films & their mechanical & electrical properties; fabricate & electrically characterize test structures; model & simulate test structure performance; communicate research results to internal customer groups. Ph.D. in Materials Science or Materials Science and Engineering. Academic project/research background in: thin films; structure/property relationships; integrated circuit (IC) fabrication using sputtering, high vacuum systems & device characterization equipment; IC fabrication technology; materials characterization techniques, including SEM, TEM & Auger; electrical characterization & testing; solid state device theory; process modeling & simulation; computer interfacing to electrical device test & measurement instruments. $55,200/yr. 40 hrs./wk. Place of employment and interview: Hillsboro, OR. If offered employment, must show legal right to work. Send this ad and your resume to: Job order #5550511, 875 Union Street, N.E., Room #201, Salem OR 97311. The company is an equal opportunity employer and fully supports affirmative action practices.

Electrical Engineer. Design hardware/software control systems for processors/equipment used in automatic container handling equipment in Europe & U.S.A.: Indramat Servo Drives; Siemens, Allen Bradley, Texas Instruments, & Modicon PLC's. Specify equipment, & establish design concepts per customer specifications. Write equipment operating description. Supervise drawing development on CAD. Implement design improvements. Commission final products in-house & on-site worldwide. Must have extensive knowledge of: British & European electrical regs, safety standards and specifications; Siemens PLC's and Indramat Servo Drives; design concepts for automated equipment control systems; electrical drawing standards & CAD; PLC programming; electrical hardware/software. Ed: B.Sc. or eqv. in Electrical Engineering. Exper: 5 yrs designing hardware & software control systems for automated equipment, including experience leading the projects & supervising engineers, & electrical designers/draftsmen. 40 hrs/wk. 7:30am-4:30pm Mon-Fri. $40,560.00/yr. Must have proof of legal authority to work in US. Send resume to: Colo Dept of Labor & Employment, Employment Programs, Attn: Rolynda Bain, 600 Grant St., #900, Denver CO 80203-3528. Refer to order #CO4156078. No phone calls please.

Electrical Engineer - Computer Automation & Control, 40hrs/wk., 9:00am - 5:00pm, $41,000/year. Analyze production facilities for computer automation and control. Obtain appropriate computer and other equipment. Supervise installation. Design/supervise installation of necessary digital data acquisition and process control systems for chemical production, including subordinate intelligent I/O microprocessor modules and systems not commercially available. Research on systems leading to patents. Design/debug appropriate real-time computer software. Supervise equipment maintenance. B.S. in Electrical Engineering as well as two years experience in job offered or as a Research Fellow required. Previous experience must include design of intelligent input-output systems for distributed chemical process control systems. Two U.S. patents/foreign equivalent or publications on subordinate intelligent microprocessor systems. Must have proof of legal authority to work permanently in the U.S. Send two copies of resume to: Illinois Department of Employment Security, 401 South State Street - 3 South, Chicago, IL 60605, Attention: Len Boksa, Reference #V-IL-10369-B. No Calls. An Employer Paid Ad.

Sofwe Engr. Seattle area employer. Design specs for real-time embedded s/w modules and systems using structured analysis techniques. Design specs for protocols and interfaces to LANs, public data networks, IBM mainframe networks, & packet radio networks. Implement & modify s/w modules and systems that provide network & RF data communications services. Implement & modify device drivers. Design & implement test tools that simulate data networks, host computers and application s/w. Conduct tests to establish compliance with specs & modify s/w modules to bring systems into compliance. Requires B.S. in Computer Science or equiv. & 4 yrs. exp. as s/w development engineer with C and IBM 370 assembler languages. Exp. must also include communications s/w dev. on IBM mainframe, UNIX, PC, & embedded real-time systems & exp w/RS-232, ethernet LAN, SDLC, HDLC/LAPD, X.25, SNA LU6.2/PU2.1, TCP/IP, & email protocols, & exp. w/IBM CICS, VTAM, 3745 NCP, 3174 cluster controller, modem, & LAN configuration & data communications standards. 40/hr wk; $45,862-55,000/yr DOE, must have proof of legal authority to work in U.S. By 9/1/93, send resume to Emp. Sec. Dept., E & T Div., Job #375053, Box 9046, Olympia, WA 98507-9046.

Variation Simulation Modeling (VSM) Engineer to conduct logical and feasibility analysis on dimensional tolerances and processing sequences of automotive parts in the real world assembly line; utilize engineering drawings, numerical analysis, and applied mathematical techniques to reduce problems to computer processable form by formulating complex mathematical models for simulation's solution utilizing VSMPC software and Fortran 77 programming languages on IBM microcomputer; consult with design process and manufacturing engineers to refine assembly process; prepare high quality graphics and technical reports using Adobe Illustrator, Professional Write, Aldus PageMaker, Lotus 123, Harvard Graphics, SPFPC, Norton Utilities, PC Tools, X-Tree Gold, Windows 3.1, Microsoft Excel for Windows, Microsoft Word for Windows, Dos. 5.0, and Novel's user software. Required Bachelor's in Electronics Engineering and two years experience as a Modeling Engineer which included creation of modular mathematical model written in FORTRAN. One year of experience must have been in automotive electric modeling. 40 hr wk. 8am - 4pm. $34,865/yr. Send resumes to 7310 Woodward Avenue, Room 415, Detroit, Michigan 48202. Reference No. 46893. Employer Paid Ad.

Senior Scientist. Responsible for creating network architectures for real-world applications, such as optical character recognition; developing software to train & test these architectures on real data & mapping architectures onto existing or new analog or digital VLSI chips; & creating neural network software for microprocessors. Reqs. Ph.D. in E.E. & 1 yr. exp. in job offered or in neural network architecture research. Also reqs. advanced knowl. (demonstrated by doctoral thesis or advanced coursework & recent publications in referreed technical journals & conference proceedings) of: neural network architectures & training algorithms, incl. backpropagation networks, temporal back-propagation networks & time-delay neural networks; knowl. of digital signal processing techniques, incl. nonlinear adaptive signal processing, knowl. of C, C++, UNIX shell, PERL, & Assembly language programming on Intel & Motorola platforms; & exp. in: DOS & Windows programming, & in custom CMOS VLSI layout using VLSI layout tools & circuit simulation software such as the Cadence design system; & implementing neural networks in both digital & analog CMOS VLSI technology & software. Salary: $60,000/yr. Send this ad w/ resume to Peter Maher, Mgr. Admin., 2698 Orchard Parkway, San Jose, CA 95134.

Test Engineer: The position is for a person to be involved in design qualification during the pre-release process of new equipment and software. In this position the worker will design, debug and implement hardware test platforms; write and maintain test plans and procedures; perform PC Hardware and Software compatibility tests under MSDOS, DRDOS, OS/2, Novell, Lantastic and Lan manager operating systems; write test software for 8051 and 80186; automatic software testing; write and maintain the Bug Tracking Data Base; verify technical documentation; perform evaluations of competitor product lines, schedule tasks and work with vendors to procure test equipment. Requires: (1) Bachelor's degree in Electrical Engineering; (2) Four (4) years in the job offered or 4 years as an Electrical Engineer; (3) The required 4 years experience must include: (1) designing and implementing hardware test platforms, (2) writing test programs for 8051, 80186 and automating software testing, (3) PC SW&HW compatibility testing including MSDOS, DRDOS, OS/2, Novell, Lantastic and Lan Manager, (4) writing and maintaining bug tracking data-bases and test plans. $38,160/yr., 40 hrs./wk., 8:30-5:00. Must have proof of legal authority to work permanently in the U.S. Send 2 copies of Resume, Diploma, and Experience Letters to: Illinois Department of Employment Security, 401 South State Street, 3 South, Chicago, IL 60605, Attn: Pete Kula, Ref. #V-IL-10371-K. No Calls. An Employer Paid Ad.

Electrical Engineer - Design hi-spd CMOS ICs. Require PhD EE and 6 mos. exp. as electrical engineer or research asst. incl. 200 mhz. designs and knowledge of Mentor GDT, LSIM and HSPICE. Interview/Job site: Cerritos, CA. Salary: $62,000 per annum. Send this ad and your resume to Job #WM45034 P.O. Box 269065, Sacramento, CA 95826-9065.

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Phd.EE (March,1994). Seeks research position in IM Drives/Industrial Electronics. Post-Doctoral offers acceptable. Reply: Ejiogu, E.C., EE Dept. Shinshu Univ. Nagano 380, Japan.

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Scanning
The Institute

New editor for Spectrum

A new editor-in-chief has been named for *IEEE Spectrum*. Murray Slovick replaced Donald Christiansen, who retired Feb. 1.

Most recently, Slovick was editor-in-chief of *Dealerscope Merchandising*, a magazine that tells retailers how to market and merchandise consumer and home office electronics and major appliances. The magazine has a 60 000-plus circulation and is owned by North American Publishing Co., Philadelphia.

Before joining *Dealerscope*, Slovick was editor-in-chief and publisher of *Industrial World*, which emphasized international activities. Earlier, he was managing editor of *Audiovideo International*. Slovick holds a bachelor of science in aeronautics and astronautics from New York University, New York City.

Sloan receives honorary degree

Martha Sloan, IEEE President and a professor of electrical engineering at Michigan Technological University, Houghton, recently received an honorary doctor of laws from Concordia University in Montreal. She was recognized for her contributions to the field of engineering and computer science and for her ground-breaking achievement as the first woman President of the IEEE.

In bestowing the degree, Concordia affirmed "its objective of encouraging women to become professional engineers," said vice-chancellor Patrick Kenniff. "Your work, as both teacher and engineer, has garnered you the esteem and respect of your peers and colleagues," he told Sloan.

In her remarks, Sloan noted that women's progress in engineering is related to how society views the profession. "More young women will pursue technology-related careers when society begins holding engineers in higher esteem," she said.

Wescon/93 to be held in San Francisco

The largest electronics exhibition and conference in the United States of original-equipment manufacturers (OEMs) returns to the Moscone Convention Center in San Francisco, Sept. 28–30. The theme of Wescon/93, "Electrifying ideas for a changing world," picks up on the developments in technology and markets that are transforming the worldwide electronics community.

The more than 1400 exhibits at the 42nd annual Wescon show will be grouped by product, including semiconductors, passive components, instrumentation, and production materials and services. Wescon will also have an OEM computer systems section and an engineering software showcase. Special exhibits will focus on emerging technologies in the electric vehicle industry and on electronic design automation, with emphasis on application-specific ICs and programmable devices.

The technical program of half-day short courses, as well as 28 applications-oriented sessions, will cover such topics as wireless communications, defense conversion, fuzzy logic and neural networks, robotics and vision systems, and energy management and portable power.

Wescon sponsors include the IEEE's San Francisco Bay Area and Los Angeles councils and the northern and southern California chapters of the Electronics Representatives Association. For information, contact Wescon/93, Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, CA 90045; 800-877-2668; fax, 310-641-5117.

Coming
in Spectrum

MODERN MANUFACTURING. As economic and market pressures build, many companies around the world are turning to leaner, more cost-effective manufacturing systems—a trend in which electrotechnology has a major part to play.

This special issue analyses the changes under way. Case studies are employed to focus such key themes as the flexibility, quality, and the precision and efficiency of manufacturing systems.

• Flexibility. A product can now be manufactured economically in lots of one—witness Advanced Digital Data's custom display terminals, among other examples.

• Quality. Motorola's technical experts report on the company's famous six-sigma quality program, now emulated worldwide.

• Precision. Because human breath can contaminate inertial systems, such machines are best assembled by compliant robot wrists. Even the measurement of such mundane items as car doors to exacting tolerances presents new challenges to metrology experts.

• Efficiency. Concurrent engineering shortens time to market and is among the driving forces of manufacturing today.

Environmental considerations impose another set of constraints in manufacturing. And all these changes make fresh demands on educators, both in academia and in the middle and high schools.

Finally, the issue looks at the intelligent manufacturing system—a multinational effort that is pointing the way to next-century industry.

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